US009306199B2

(12) **United States Patent**
Merriman et al.

(10) **Patent No.: US 9,306,199 B2**
(45) **Date of Patent: Apr. 5, 2016**

(54) **BATTERY MODULE AND METHOD FOR ASSEMBLING THE BATTERY MODULE**

(75) Inventors: **Robert Merriman**, Shelby Township, MI (US); **Anthony Arena**, Macomb, MI (US); **David Beltz**, Troy, MI (US); **Greg Phillips**, White Lake, MI (US); **Michael Garascia**, Waterford, MI (US); **Heekook Yang**, Troy, MI (US)

(73) Assignee: **LG Chem, Ltd.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 885 days.

(21) Appl. No.: **13/587,030**

(22) Filed: **Aug. 16, 2012**

(65) **Prior Publication Data**

US 2014/0050966 A1 Feb. 20, 2014

(51) **Int. Cl.**

H01M 10/04	(2006.01)
H01M 2/10	(2006.01)
H01M 10/0525	(2010.01)
H01M 10/6557	(2014.01)
H01M 10/6566	(2014.01)

(52) **U.S. Cl.**

CPC ***H01M 2/1061*** (2013.01); ***H01M 2/1016*** (2013.01); ***H01M 2/1077*** (2013.01); ***H01M 10/0468*** (2013.01); ***H01M 10/0481*** (2013.01); *H01M 10/0525* (2013.01); *H01M 10/6557* (2015.04); *H01M 10/6566* (2015.04); *Y02E 60/122* (2013.01); *Y10T 29/49108* (2015.01)

(58) **Field of Classification Search**

CPC H01M 10/0468; H01M 2/1016
USPC 429/163
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,587,425	A	6/1926	Otto
2,273,244	A	2/1942	Cornelius
2,391,859	A	1/1946	Earl
3,503,558	A	3/1970	Galiulo et al.
3,522,100	A	7/1970	Lindstrom

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1385917	A	12/2002
CN	101101997	A	1/2008

(Continued)

OTHER PUBLICATIONS

Mavrigian, HPBooks High Performance Fasteners & Plumbing, Jan. 2008, Penguin Group, First Edition, pp. 13-14.*

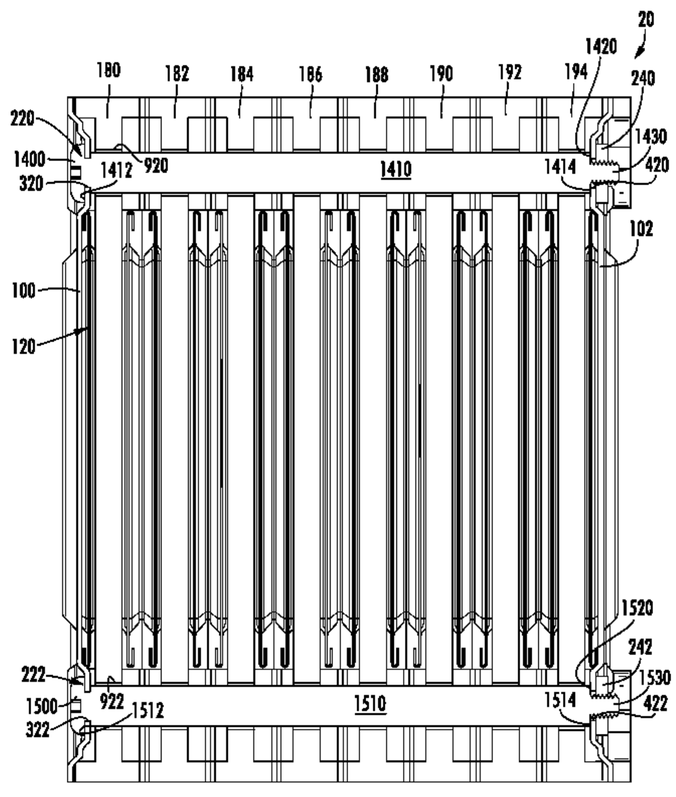
(Continued)

Primary Examiner — Jonathan G Leong
(74) *Attorney, Agent, or Firm* — Buckert Patent & Trademark Law Firm, PC; John F. Buckert

(57) **ABSTRACT**

A battery module and a method for assembling the battery module are provided. The battery module includes a first end plate, a second end plate, a frame member, a first battery cell disposed between the first end plate and the frame member, and a second battery cell disposed between the second end plate and the frame member. The battery module further includes a first shoulder bolt having a first head portion, a first shaft portion, a first shoulder portion, and a first threaded portion. The first shoulder bolt is disposed such that the first head portion is disposed against the first end plate and the first shaft portion extends through a first aperture of the first end plate and a first aperture of the frame member, and the first shoulder portion is disposed against the second end plate.

15 Claims, 26 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

3,550,681	A	12/1970	Stier et al.
3,964,930	A	6/1976	Reiser
4,009,752	A	3/1977	Wilson
4,063,590	A	12/1977	Mcconnell
4,298,904	A	11/1981	Koenig
4,305,456	A	12/1981	Mueller et al.
4,322,776	A	3/1982	Job et al.
4,444,994	A	4/1984	Baker et al.
4,518,663	A	5/1985	Kodali et al.
4,646,202	A	2/1987	Hook et al.
4,701,829	A	10/1987	Bricaud et al.
4,777,561	A	10/1988	Murphy et al.
4,849,858	A	7/1989	Grapes et al.
4,982,785	A	1/1991	Tomlinson
4,995,240	A	2/1991	Barthel et al.
5,057,968	A	10/1991	Morrison
5,071,652	A	12/1991	Jones et al.
5,186,250	A	2/1993	Ouchi et al.
5,214,564	A	5/1993	Metzler et al.
5,270,131	A	12/1993	Diethelm et al.
5,322,745	A	6/1994	Yanagihara et al.
5,329,988	A	7/1994	Juger
5,346,786	A	9/1994	Hodgetts
5,356,735	A	10/1994	Meadows et al.
5,392,873	A	2/1995	Masuyama et al.
5,443,926	A	8/1995	Holland et al.
5,510,203	A	4/1996	Hamada et al.
5,520,976	A	5/1996	Giannetti et al.
5,663,007	A	9/1997	Ikoma et al.
5,736,836	A	4/1998	Hasegawa et al.
5,756,227	A	5/1998	Suzuki et al.
5,937,664	A	8/1999	Matsuno et al.
5,985,483	A	11/1999	Verhoog et al.
6,087,036	A	7/2000	Rouillard et al.
6,111,387	A	8/2000	Kouzu et al.
6,159,630	A	12/2000	Wyser
6,176,095	B1	1/2001	Porter
6,289,979	B1	9/2001	Kato
6,344,728	B1	2/2002	Kouzu et al.
6,362,598	B2	3/2002	Laig-Horstebrock et al.
6,399,238	B1	6/2002	Oweis et al.
6,422,027	B1	7/2002	Coates, Jr. et al.
6,448,741	B1	9/2002	Inui et al.
6,462,949	B1	10/2002	Parish, IV et al.
6,512,347	B1	1/2003	Hellmann et al.
6,569,556	B2	5/2003	Zhou et al.
6,662,891	B2	12/2003	Misu et al.
6,689,510	B1	2/2004	Gow et al.
6,696,197	B2	2/2004	Inagaki et al.
6,724,172	B2	4/2004	Koo
6,750,630	B2	6/2004	Inoue et al.
6,775,998	B2	8/2004	Yuasa et al.
6,780,538	B2	8/2004	Hamada et al.
6,821,671	B2	11/2004	Hinton et al.
6,826,948	B1	12/2004	Bhatti et al.
6,878,485	B2	4/2005	Ovshinsky et al.
6,982,131	B1	1/2006	Hamada et al.
7,070,874	B2	7/2006	Blanchet et al.
7,143,124	B2	11/2006	Garthwaite
7,150,935	B2	12/2006	Hamada et al.
7,250,741	B2	7/2007	Koo et al.
7,264,902	B2	9/2007	Horie et al.
7,278,389	B2	10/2007	Kirakosyan
7,467,525	B1	12/2008	Ohta et al.
7,531,270	B2	5/2009	Buck et al.
7,591,303	B2	9/2009	Zeigler et al.
7,795,845	B2	9/2010	Cho
7,797,958	B2	9/2010	Alston et al.
7,816,029	B2	10/2010	Takamatsu et al.
7,846,573	B2	12/2010	Kelly
7,879,480	B2	2/2011	Yoon et al.
7,883,793	B2	2/2011	Niedzwiecki et al.
7,976,978	B2	7/2011	Shin et al.
7,981,538	B2	7/2011	Kim et al.
7,997,367	B2	8/2011	Nakamura
8,007,915	B2	8/2011	Kurachi
8,011,467	B2	9/2011	Asao et al.
8,030,886	B2	10/2011	Mahalingam et al.
8,067,111	B2	11/2011	Koetting et al.
8,209,991	B2	7/2012	Kondou et al.
8,409,743	B2	4/2013	Okada et al.
8,663,829	B2	3/2014	Koetting et al.
2002/0012833	A1	1/2002	Gow et al.
2002/0086201	A1	7/2002	Payen et al.
2002/0182493	A1	12/2002	Ovshinsky et al.
2003/0017384	A1	1/2003	Marukawa et al.
2003/0080714	A1	5/2003	Inoue et al.
2003/0189104	A1	10/2003	Watanabe et al.
2003/0211384	A1	11/2003	Hamada et al.
2004/0069474	A1	4/2004	Wu et al.
2004/0121205	A1	6/2004	Blanchet
2005/0026014	A1	2/2005	Fogaing et al.
2005/0089750	A1	4/2005	Ng et al.
2005/0103486	A1	5/2005	Demuth et al.
2005/0110460	A1	5/2005	Arai et al.
2005/0134038	A1	6/2005	Walsh
2006/0234119	A1	10/2006	Kruger et al.
2006/0286450	A1	12/2006	Yoon et al.
2007/0062681	A1	3/2007	Beech
2007/0087266	A1	4/2007	Bourke et al.
2007/0227166	A1	10/2007	Rafalovich et al.
2008/0003491	A1	1/2008	Yahnker et al.
2008/0041079	A1	2/2008	Nishijima et al.
2008/0110189	A1	5/2008	Alston et al.
2008/0110606	A1	5/2008	Gorbounov et al.
2008/0182151	A1	7/2008	Mizusaki et al.
2008/0248338	A1	10/2008	Yano et al.
2008/0299446	A1	12/2008	Kelly
2008/0314071	A1	12/2008	Ohta et al.
2009/0074478	A1	3/2009	Kurachi
2009/0087727	A1	4/2009	Harada et al.
2009/0104512	A1	4/2009	Fassnacht et al.
2009/0123819	A1	5/2009	Kim
2009/0155680	A1	6/2009	Maguire et al.
2009/0186265	A1	7/2009	Koetting et al.
2009/0258288	A1	10/2009	Weber et al.
2009/0258289	A1	10/2009	Weber et al.
2009/0280395	A1	11/2009	Nemesh et al.
2009/0325051	A1	12/2009	Niedzwiecki et al.
2009/0325052	A1	12/2009	Koetting et al.
2009/0325054	A1	12/2009	Payne et al.
2009/0325055	A1	12/2009	Koetting et al.
2009/0325059	A1	12/2009	Niedzwiecki et al.
2010/0112419	A1	5/2010	Jang et al.
2010/0203376	A1	8/2010	Choi et al.
2010/0209760	A1	8/2010	Yoshihara et al.
2010/0262791	A1	10/2010	Gilton
2010/0275619	A1	11/2010	Koetting et al.
2010/0276132	A1	11/2010	Payne
2010/0279152	A1	11/2010	Payne
2010/0279154	A1	11/2010	Koetting et al.
2010/0304203	A1	12/2010	Buck et al.
2010/0307723	A1	12/2010	Thomas et al.
2011/0000241	A1	1/2011	Favaretto
2011/0020676	A1	1/2011	Kurosawa
2011/0027631	A1	2/2011	Koenigsmann
2011/0027640	A1	2/2011	Gadawski et al.
2011/0041525	A1	2/2011	Kim et al.
2011/0045326	A1	2/2011	Leuthner et al.
2011/0052959	A1	3/2011	Koetting et al.
2011/0052960	A1	3/2011	Kwon et al.
2011/0189523	A1	8/2011	Eom
2011/0293982	A1	12/2011	Martz et al.
2011/0293983	A1	12/2011	Oury et al.
2012/0082880	A1	4/2012	Koetting et al.
2012/0156537	A1*	6/2012	Meintschel et al. 429/99
2012/0156542	A1	6/2012	Schaefer et al.
2012/0171543	A1	7/2012	Hirsch et al.
2012/0183830	A1	7/2012	Schaefer et al.
2013/0045410	A1	2/2013	Yang et al.
2013/0136136	A1	5/2013	Ando et al.
2013/0255293	A1	10/2013	Gadawski et al.
2013/0309542	A1	11/2013	Merriman et al.
2014/0050953	A1	2/2014	Yoon et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2014/0050966	A1	2/2014	Merriman et al.
2014/0120390	A1	5/2014	Merriman et al.
2014/0147709	A1	5/2014	Ketkar et al.
2014/0227575	A1	8/2014	Ketkar
2014/0308558	A1	10/2014	Merriman et al.
2015/0010801	A1	1/2015	Arena et al.
2015/0111075	A1	4/2015	Yum et al.

FOREIGN PATENT DOCUMENTS

CN	1754279	B	9/2010
DE	19639115	A	3/1998
DE	102008034860	A1	1/2010
DE	102009006426	A1	7/2010
DE	102010021922	A1	12/2011
EP	1577966	A	9/2005
EP	1852925	A	11/2007
EP	2065963	A2	6/2009
EP	2200109	A2	6/2010
EP	2262048	A	12/2010
GB	481891	A	3/1938
JP	08111244		4/1996
JP	09129213		5/1997
JP	19970199186		7/1997
JP	09219213		8/1997
JP	2001105843	A	4/2001
JP	2002038033	A	2/2002
JP	2002319383	A	10/2002
JP	2002333255	A	11/2002
JP	2003188323	A	7/2003
JP	2003282112	A	10/2003
JP	2004333115	A	11/2004
JP	2005126315	A	5/2005
JP	2005147443	A	6/2005
JP	2005349955	A	12/2005
JP	2006512731		4/2006
JP	2006125835		5/2006
JP	2006139928	A	6/2006
JP	2007107684		4/2007
JP	2007305425	A	11/2007
JP	2008054379	A	3/2008
JP	2008062875	A	3/2008
JP	2008080995	A	4/2008
JP	2008159440	A	7/2008
JP	2009009889	A	1/2009
JP	2009054297	A	3/2009
KR	20050092605	A	9/2005
KR	100637472	B1	10/2006
KR	100765659	B1	10/2007
KR	20080047641	A	5/2008
KR	20090082212	A	7/2009
KR	100921346	B1	10/2009
KR	20090107443	A	10/2009
KR	1020100119497	A	11/2010
KR	1020100119498	A	11/2010
KR	1020110013270	A	2/2011
KR	20110126764	A	11/2011
WO	2006083446	A2	8/2006
WO	2006101343	A	9/2006
WO	2007007503	A	1/2007
WO	2007115743	A2	10/2007
WO	2008111162	A	9/2008
WO	2009073225	A	6/2009
WO	WO 2010081704	A2 *	7/2010
WO	2011145830	A2	11/2011

OTHER PUBLICATIONS

"Gasket". Merriam-Webster. Merriam-Webster. Web. May 30, 2012. <http://www.merriam-webster.com/dictionary/gasket>.

International Search Report; International Application No. PCT/KR2009/000258; International Filing Date: Jan. 16, 2009; Date of Mailing: Aug. 28, 2009; 2 pages.

International Search Report; International Application No. PCT/KR2009/003428, International Filing Date: Jun. 25, 2009; Date of Mailing: Jan. 22, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2009/003429; International Filing Date: Jun. 25, 2009; Date of Mailing: Jan. 12, 2010; 3 pages.

International Search Report; International Application No. PCT/KR2009/003430; International Filing Date: Jun. 25, 2009; Date of Mailing: Feb. 3, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2009/003434; International Filing Date: Jun. 25, 2009; Date of Mailing: Jan. 18, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2009/003436; International Filing Date: Jun. 25, 2009; Date of Mailing: Jan. 22, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2009/006121; International Filing Date: Oct. 22, 2009; Date of Mailing: May 3, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2010/002334; International Filing Date: Apr. 15, 2010; Date of Mailing: Nov. 29, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2010/002336; International Filing Date: Apr. 15, 2010; Date of Mailing: Jan. 31, 2011; 2 pages.

International Search Report; International Application No. PCT/KR2010/002337; International Filing Date: Apr. 15, 2010; Date of Mailing: May 3, 2010; 2 pages.

International Search Report; International Application No. PCT/KR2010/002340; International Filing Date: Apr. 15, 2010; Date of Mailing: Jan. 31, 2011; 2 pages.

International Search Report; International Application No. PCT/KR2010/004944; International Filing Date: Jul. 28, 2010; Date of Mailing: Apr. 29, 2011; 2 pages.

International Search Report; International Application No. PCT/KR2010/005639; International Filing Date: Aug. 24, 2010; Date of Mailing: Jun. 3, 2011; 2 pages.

Machine translation of Japanese Patent Application No. 2009-009889 A, published Jan. 15, 2009.

Thomas J. Gadawski et al., pending U.S. Appl. No. 13/433,649 entitled "Battery System and Method for Cooling the Battery System," filed Mar. 29, 2012.

U.S. Appl. No. 13/475,963, filed May 19, 2012 entitled Battery Cell Assembly and Method for Manufacturing a Cooling Fin for the Battery Cell Assembly.

U.S. Appl. No. 13/586,960, filed Aug. 16, 2012 entitled Battery Module.

International Search Report for International application No. PCT/KR2013/004015 dated Sep. 26, 2013.

U.S. Appl. No. 14/161,806, filed Jan. 23, 2014 entitled Battery Cell Assembly and Method for Coupling a Cooling Fin to First and Second Cooling Manifolds.

U.S. Appl. No. 14/273,572, filed May 9, 2014 entitled Battery Pack and Method of Assembling the Battery Pack.

U.S. Appl. No. 14/273,586, filed May 9, 2014 entitled Battery Module and Method of Assembling the Battery Module.

U.S. Appl. No. 14/328,000, filed Jul. 10, 2014 entitled Battery System and Method of Assembling the Battery System.

U.S. Appl. No. 14/330,163, filed Jul. 14, 2014 entitled Battery System and Method for Cooling the Battery System.

U.S. Appl. No. 14/511,389, filed Oct. 10, 2014 entitled Battery Cell Assembly.

U.S. Appl. No. 14/516,667, filed Oct. 17, 2014 entitled Battery Cell Assembly.

U.S. Appl. No. 14/531,696, filed Nov. 3, 2014 entitled Battery Pack.

Written Opinion for International application No. PCT/KR2013002597 dated Feb. 2, 2015.

Written Opinion for International application No. PCT/KR2014/002090 dated May 26, 2014.

* cited by examiner

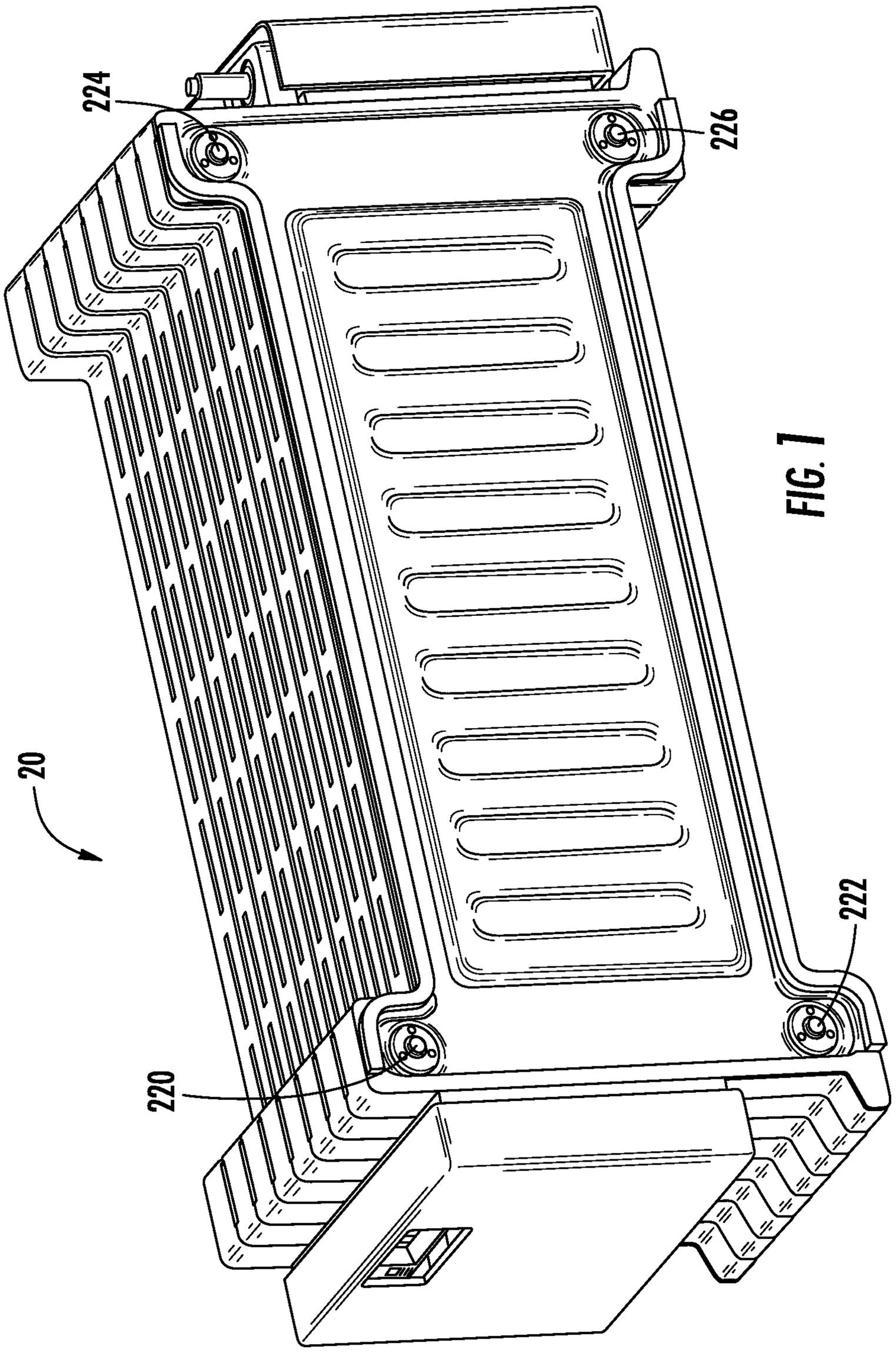


FIG. 1

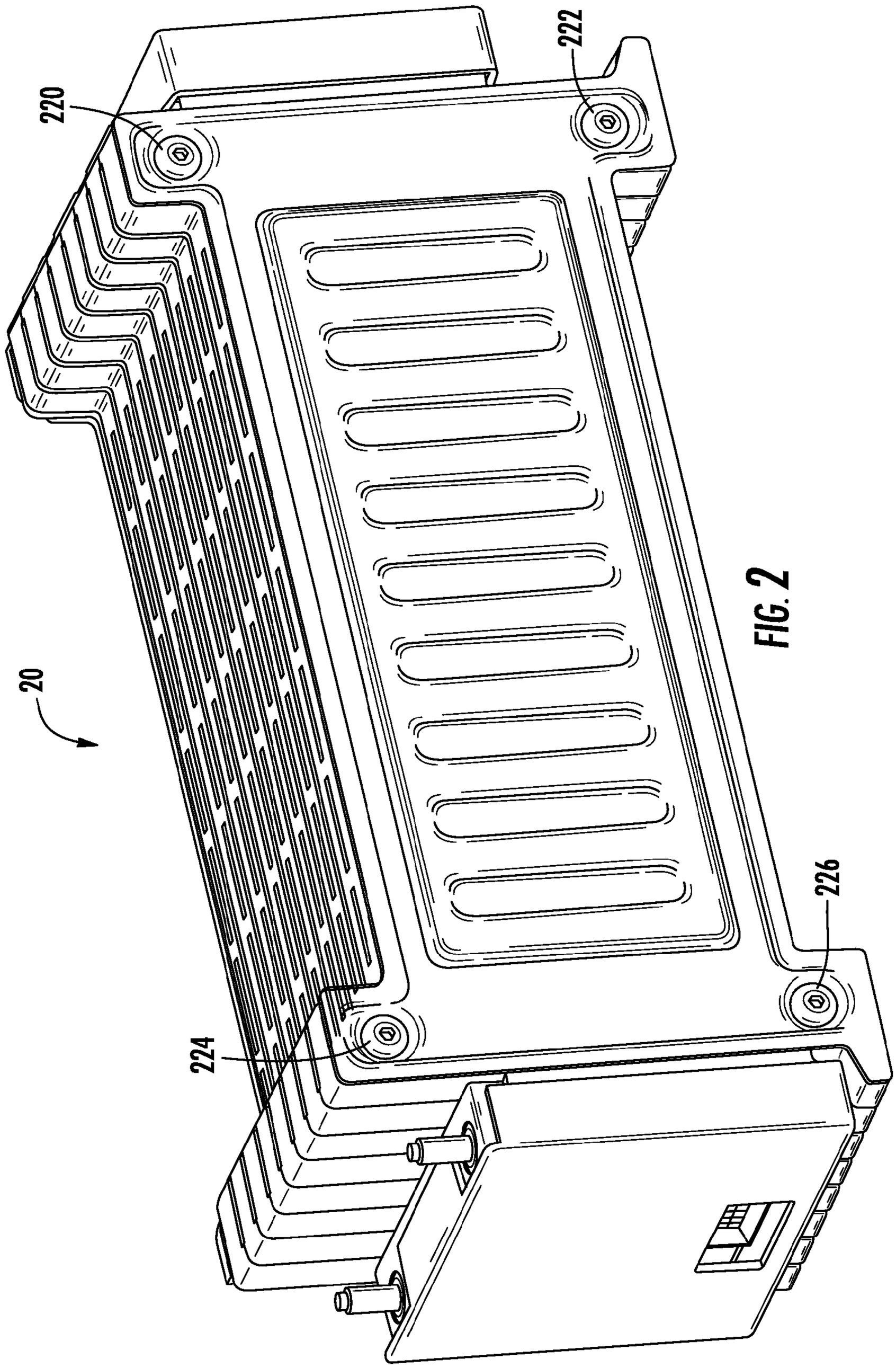


FIG. 2

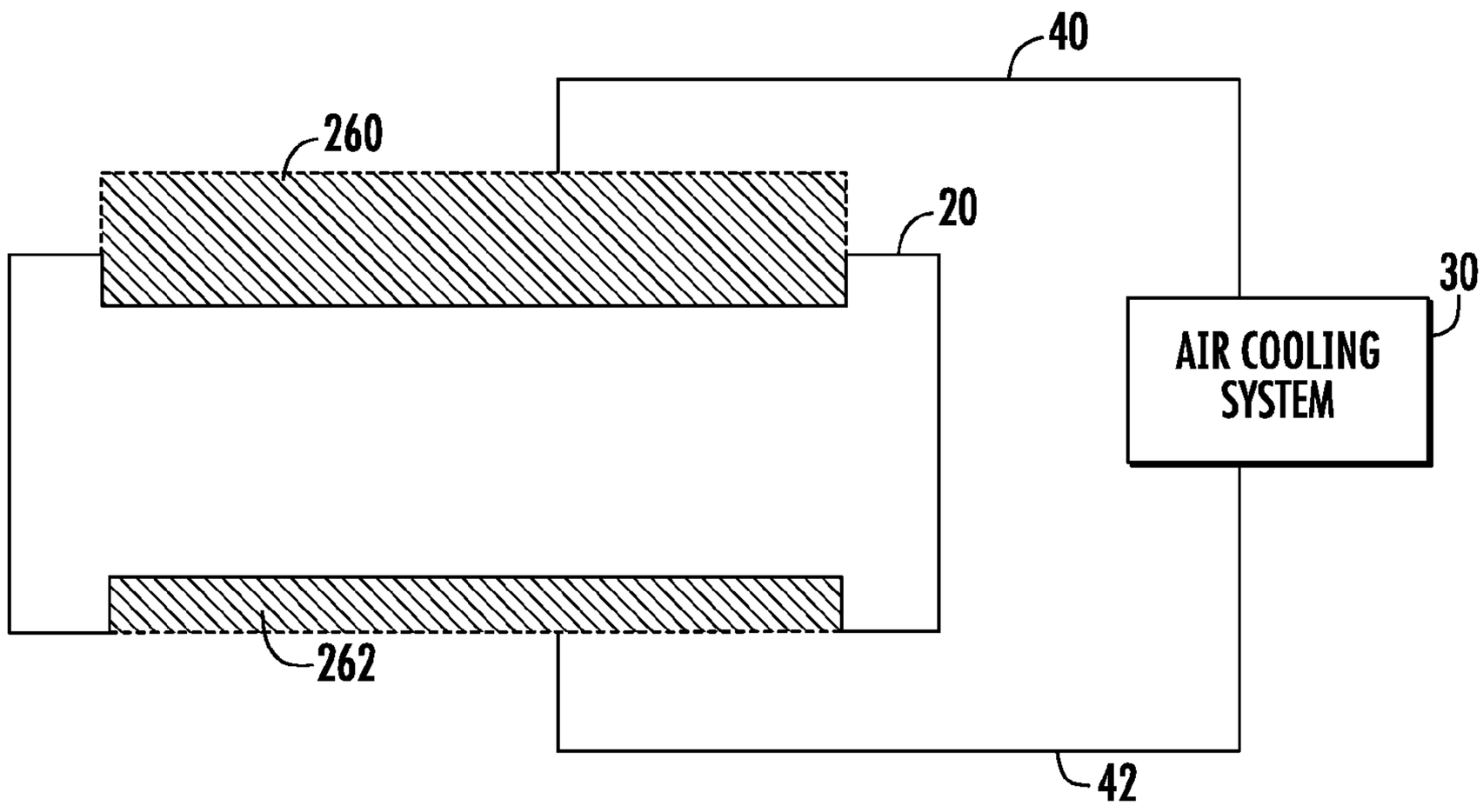


FIG. 3

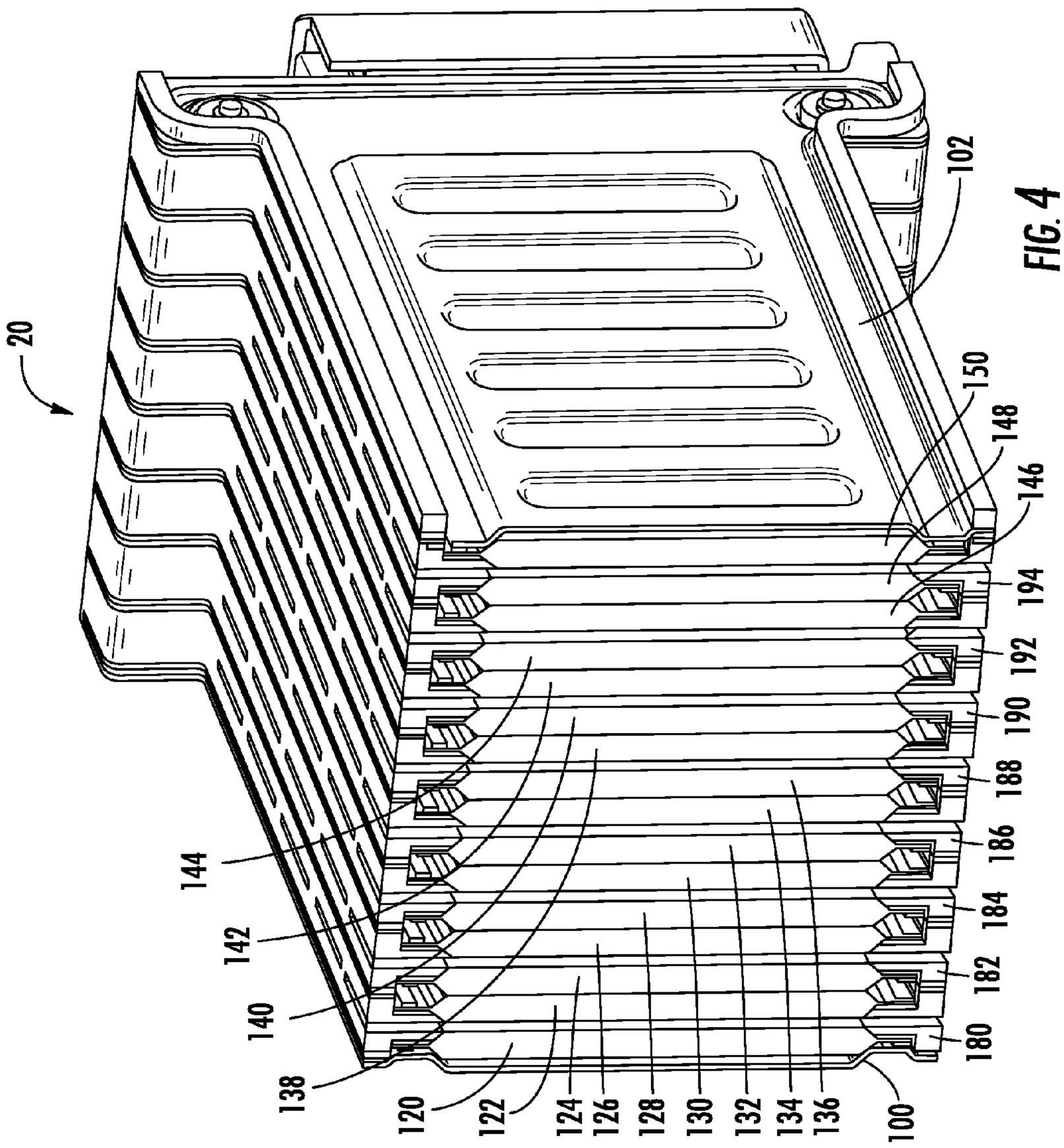

20
102
150
148
146
194
192
190
188
186
184
182
180
144
142
140
138
120
122
124
126
128
130
132
134
136
100

FIG. 4

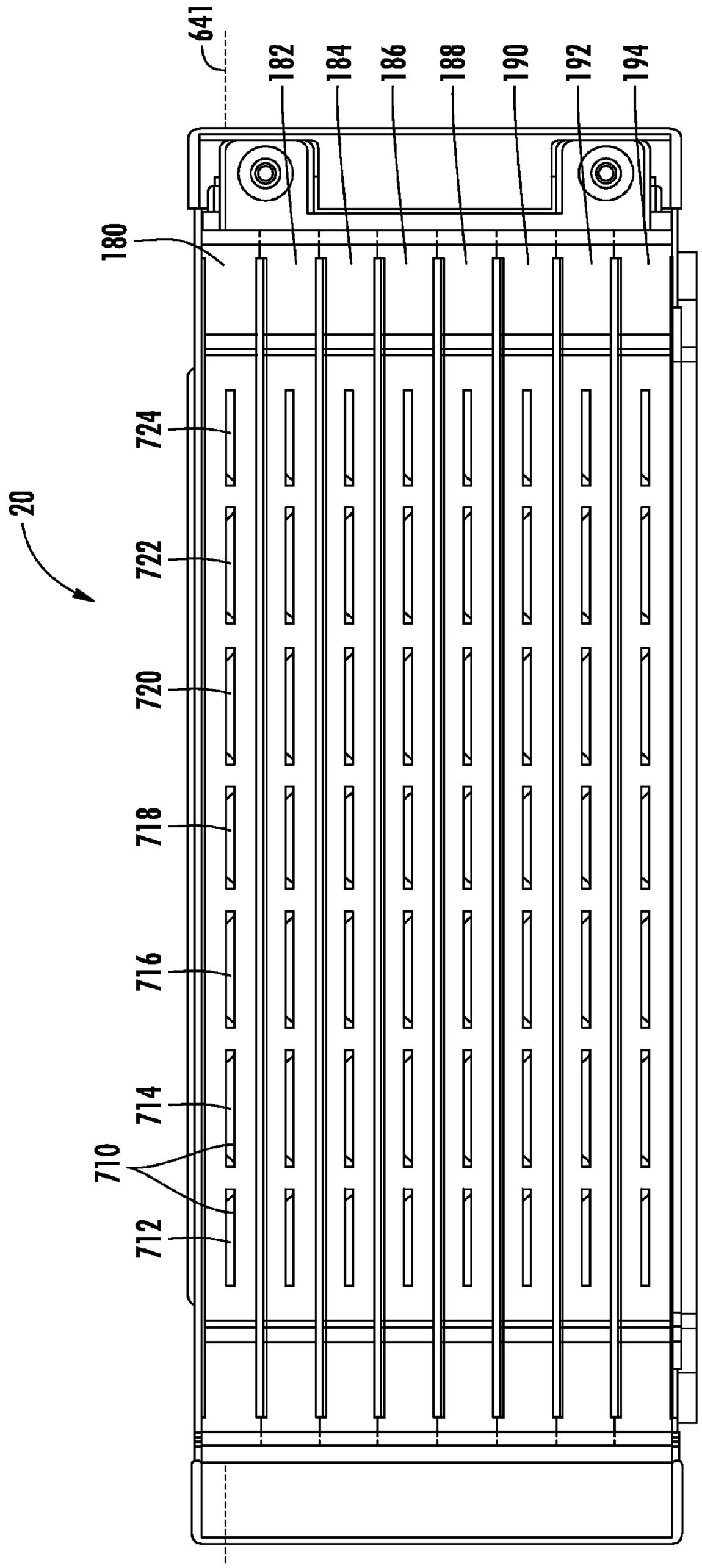

641
182
184
186
188
190
192
194
180
20
724
722
720
718
716
714
710
712

FIG. 5

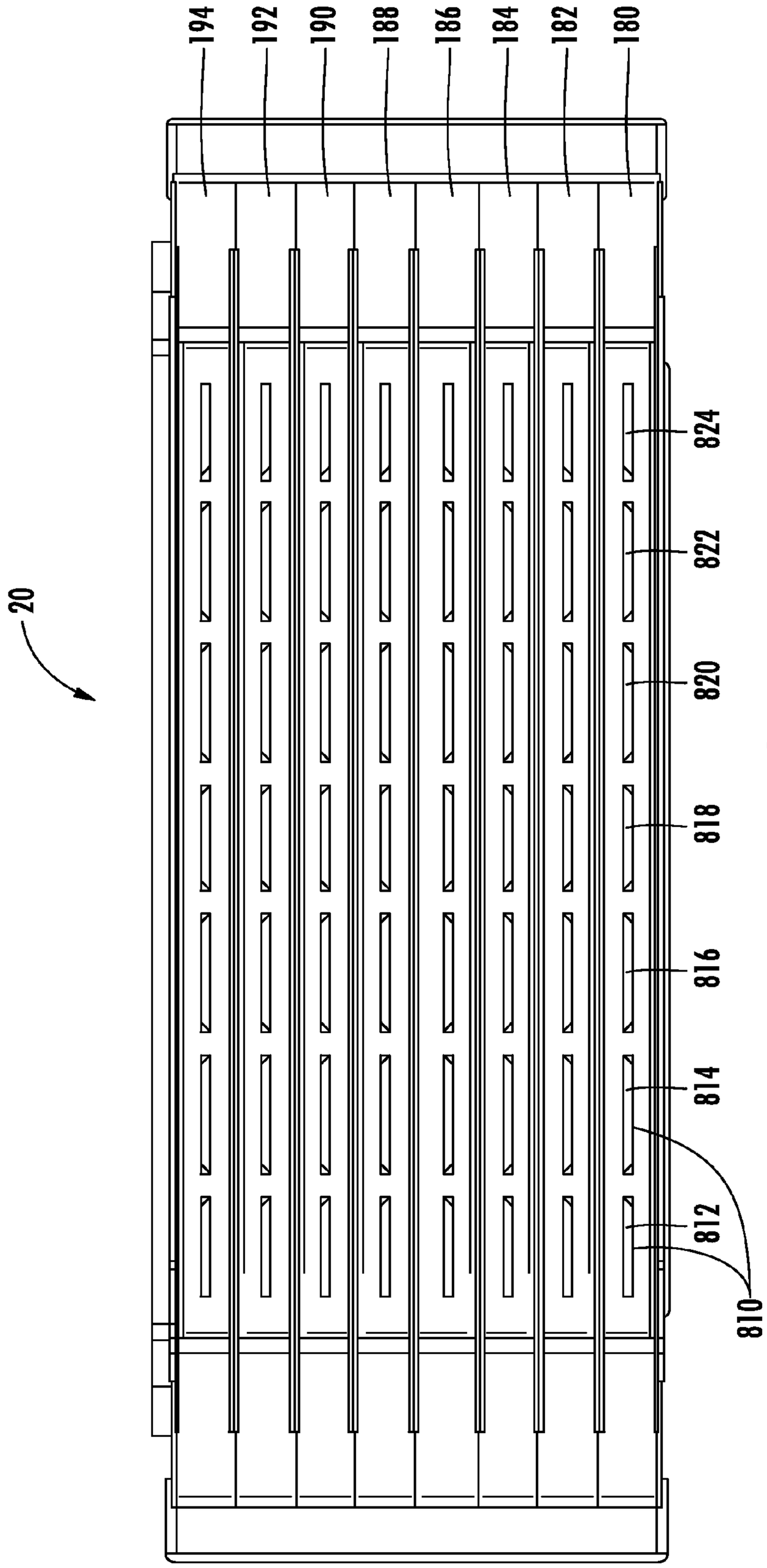

194
192
190
188
186
184
182
180
20
824
822
820
818
816
814
812
810

FIG. 6

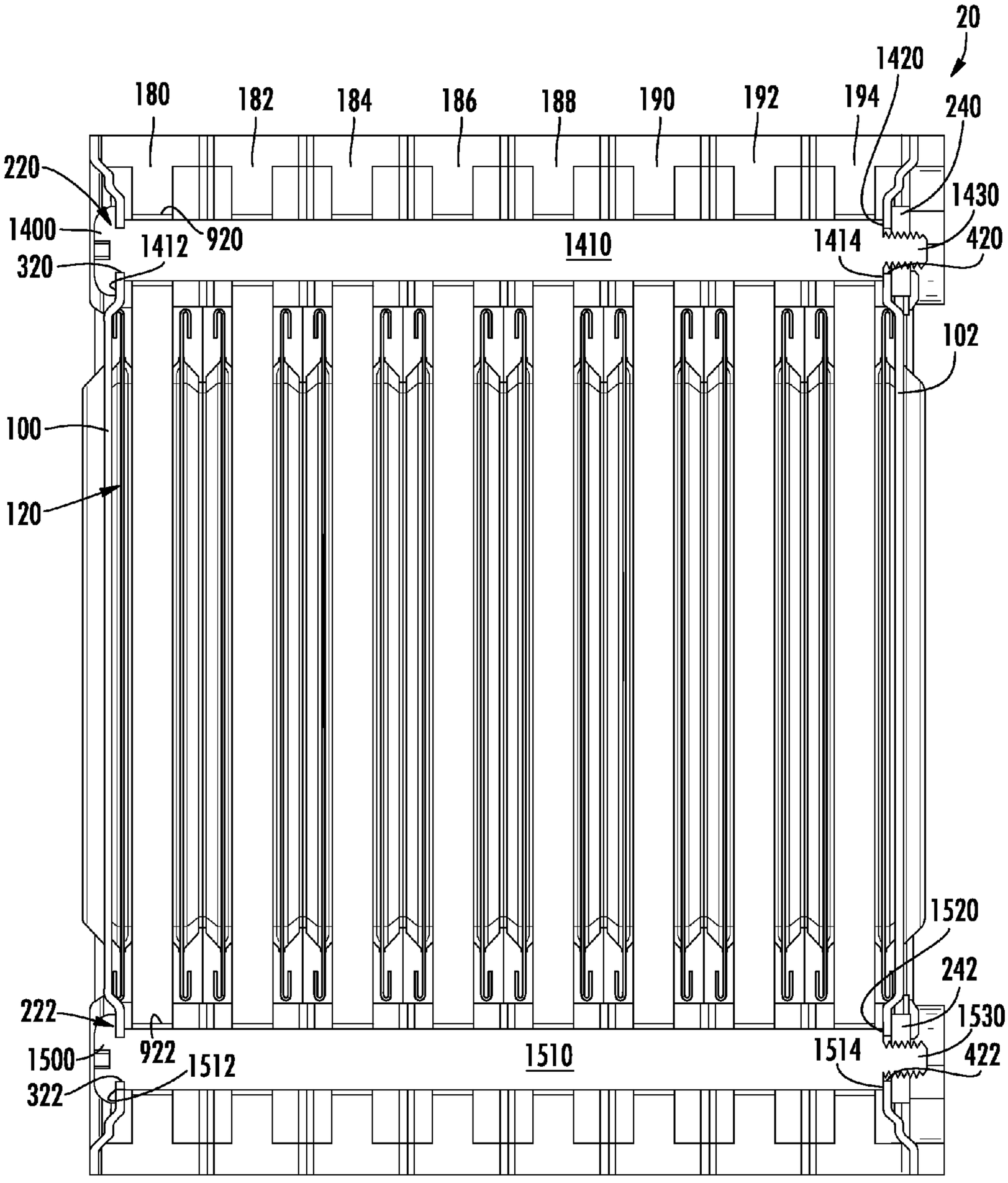
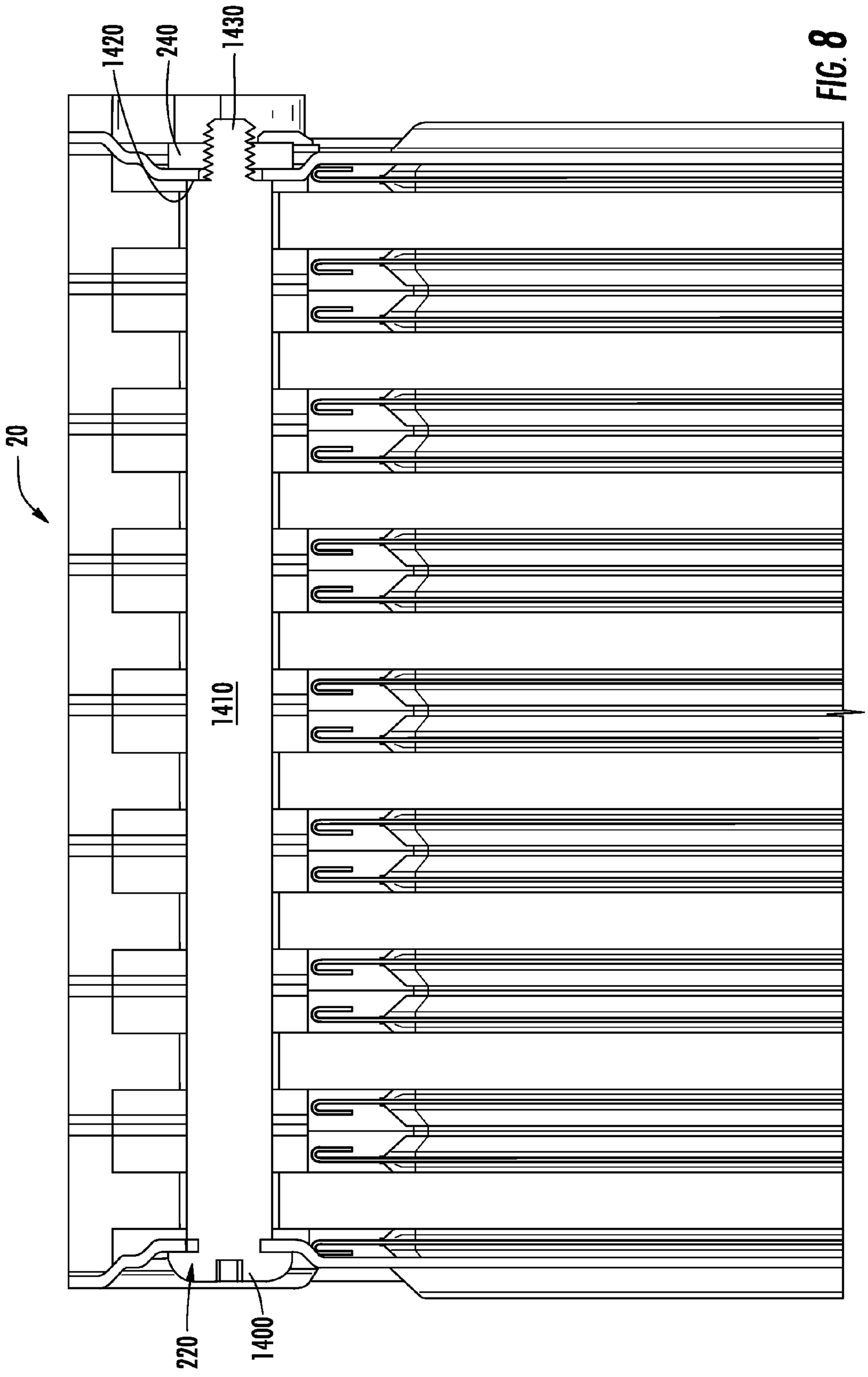

20
1420
180
182
184
186
188
190
192
194
240
220
1430
1400
1412
920
1410
1414
420
320
102
100
120
1520
242
222
1530
922
1500
1512
1510
1514
422
322

FIG. 7

FIG. 8



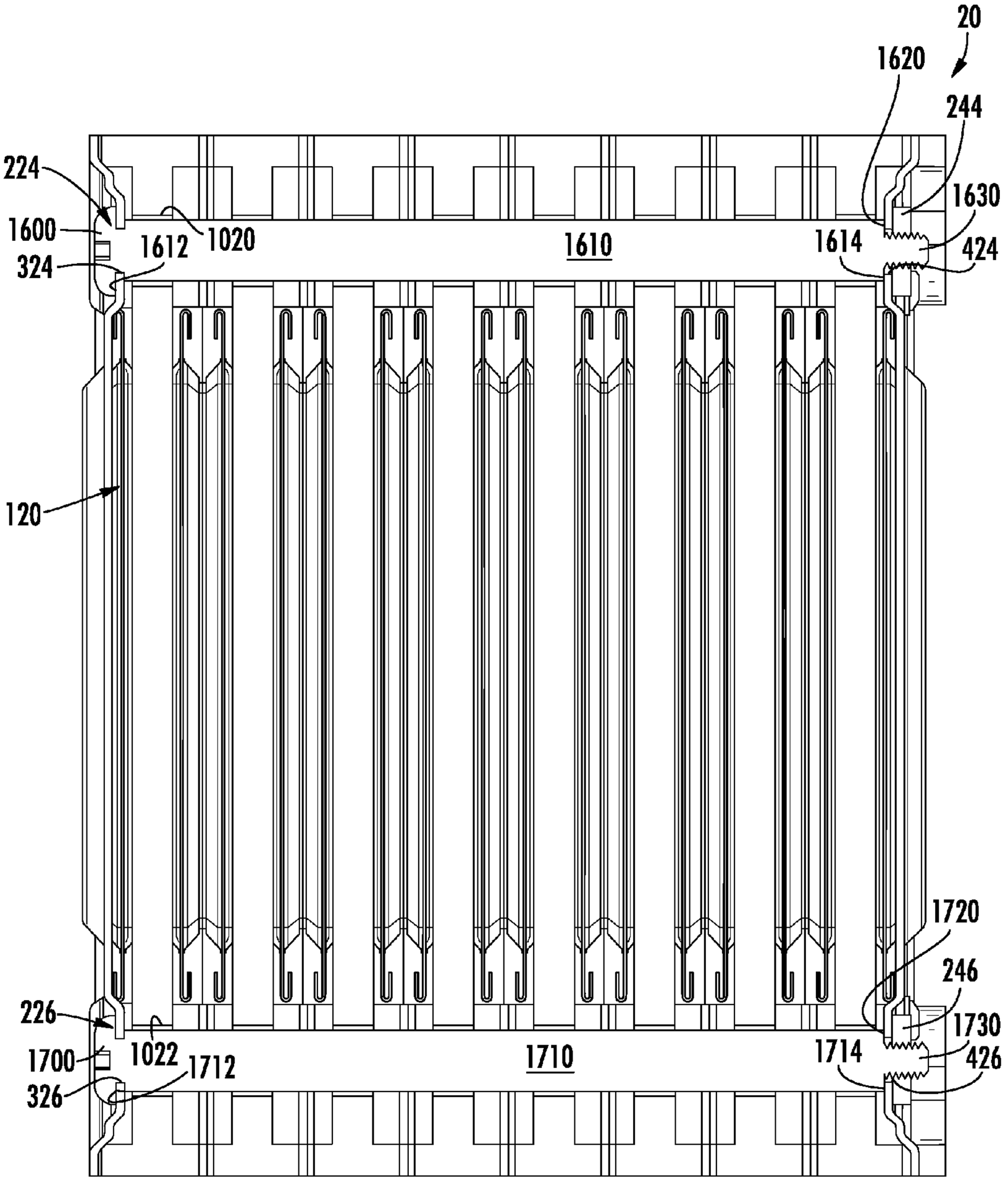

20
1620
244
224
1630
1600
1612
1020
1610
1614
424
324
120
1720
246
226
1730
1700
1022
1712
1710
1714
426
326

FIG. 9

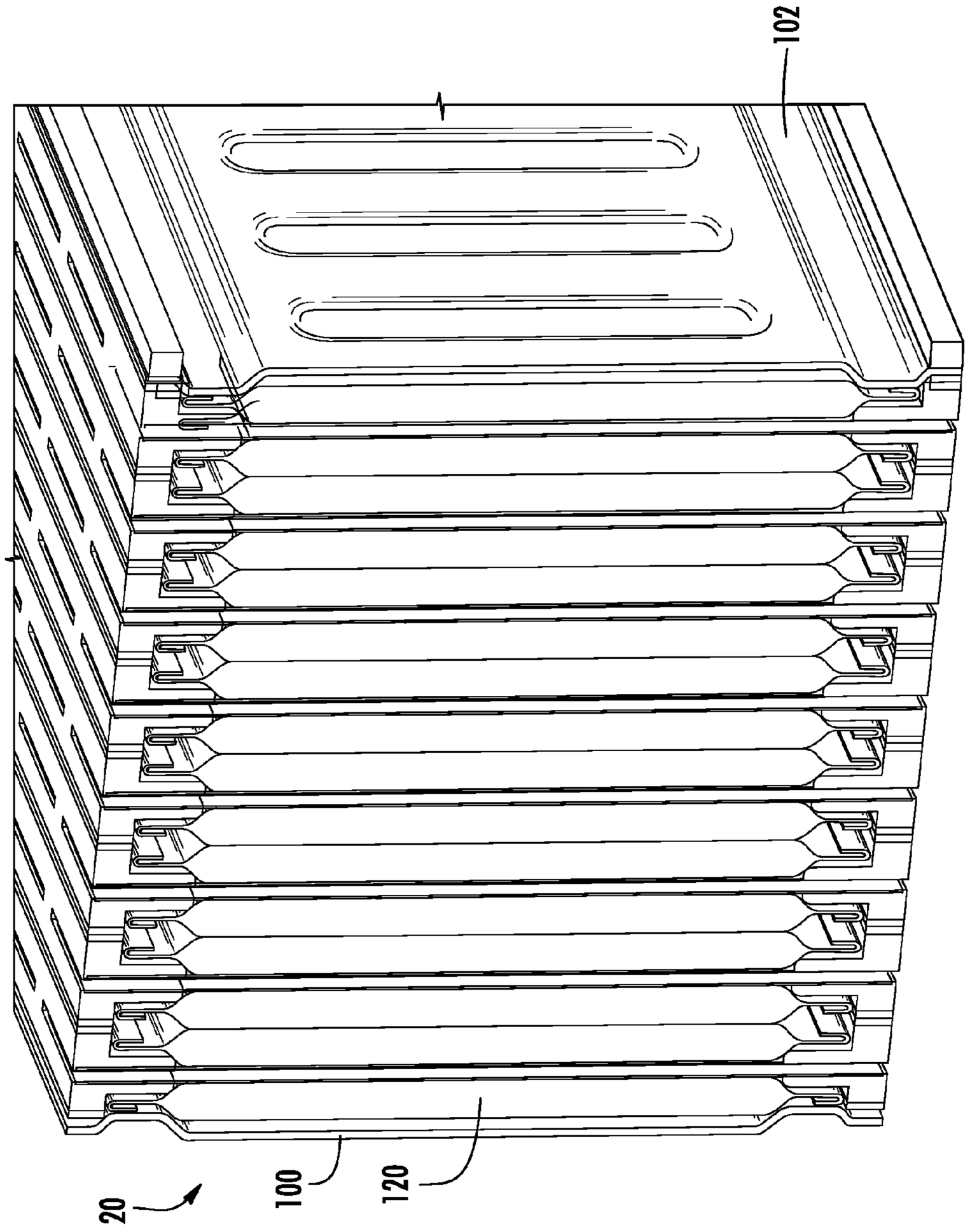


FIG. 10

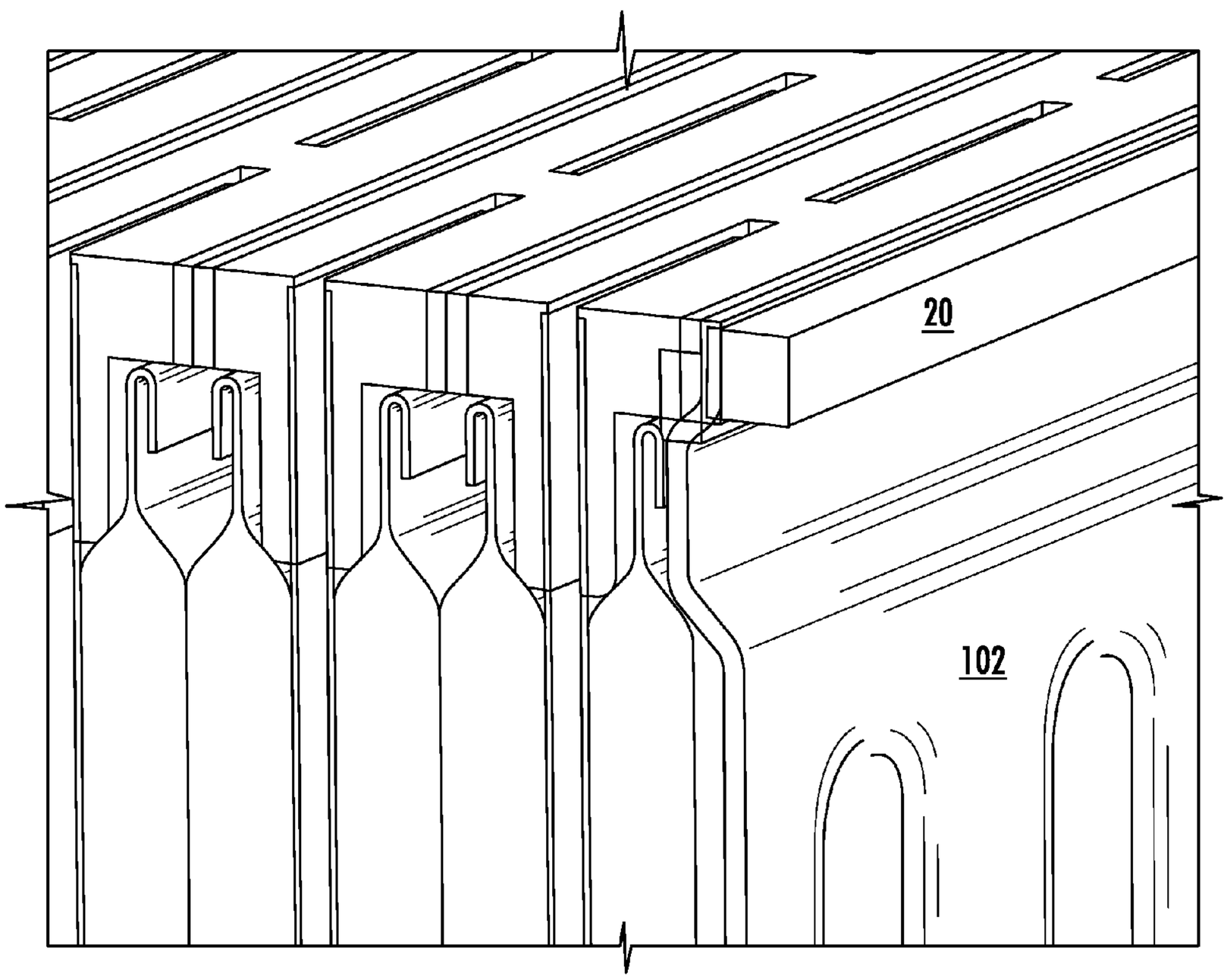


FIG. 11

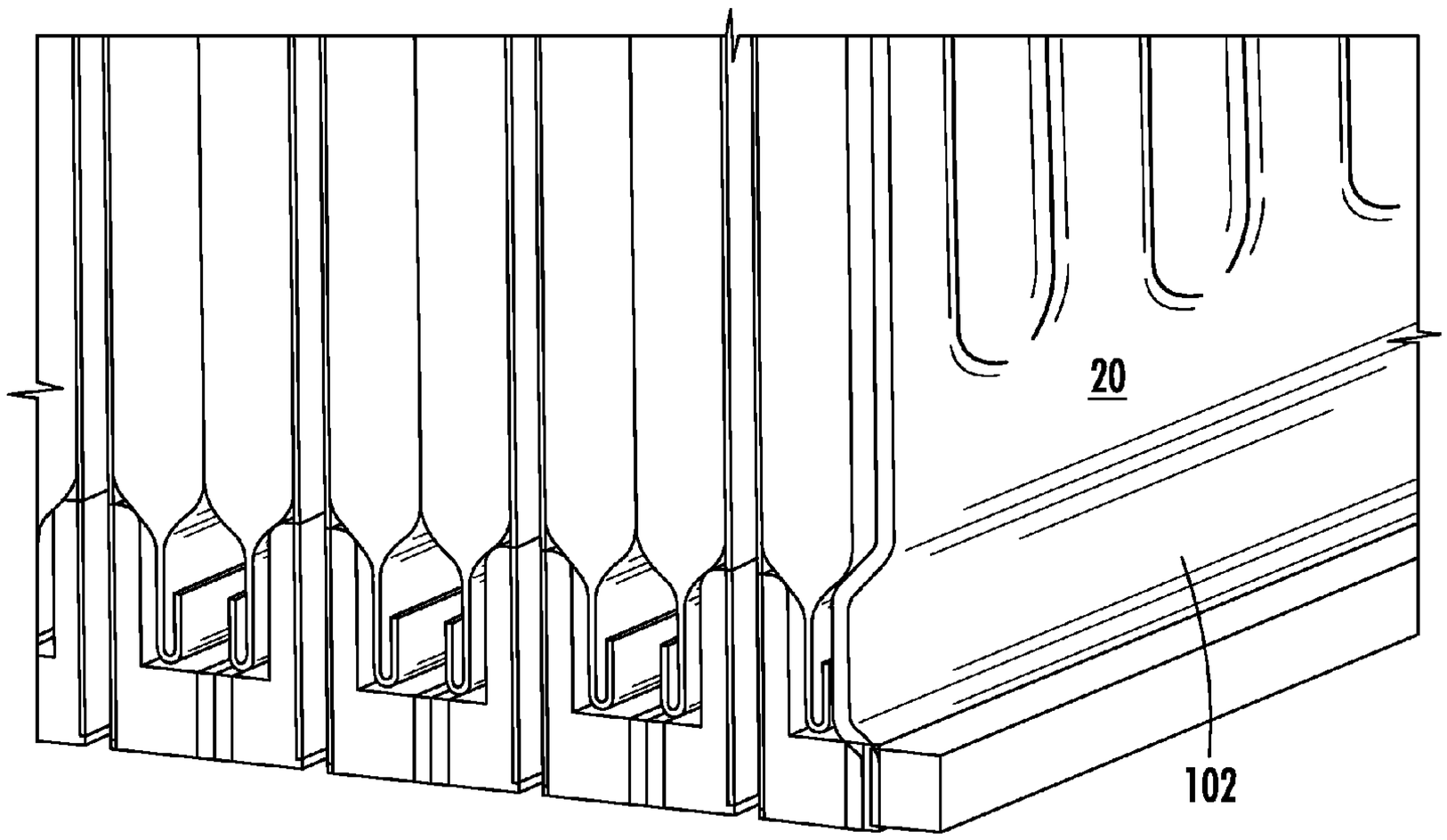


FIG. 12

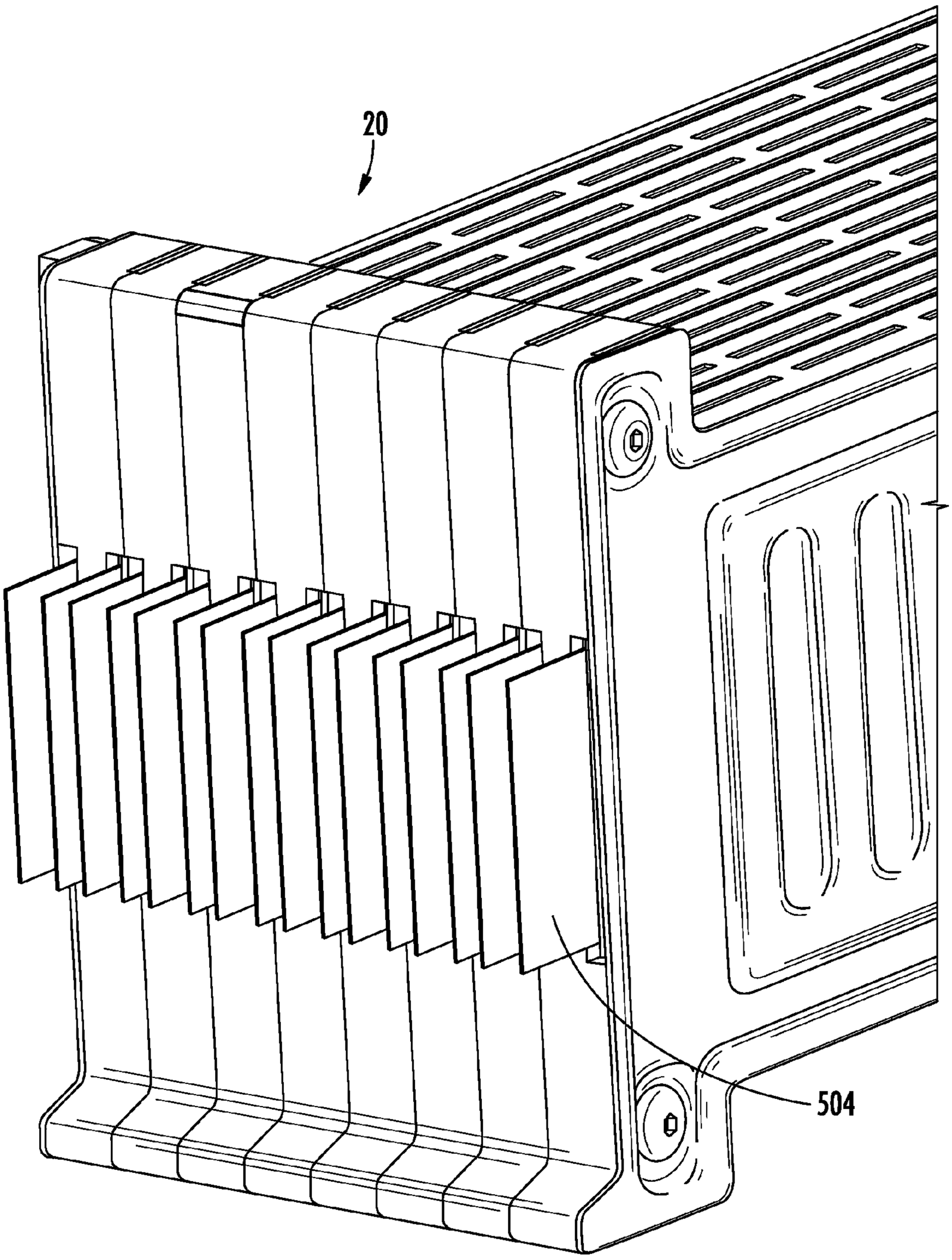


FIG. 13

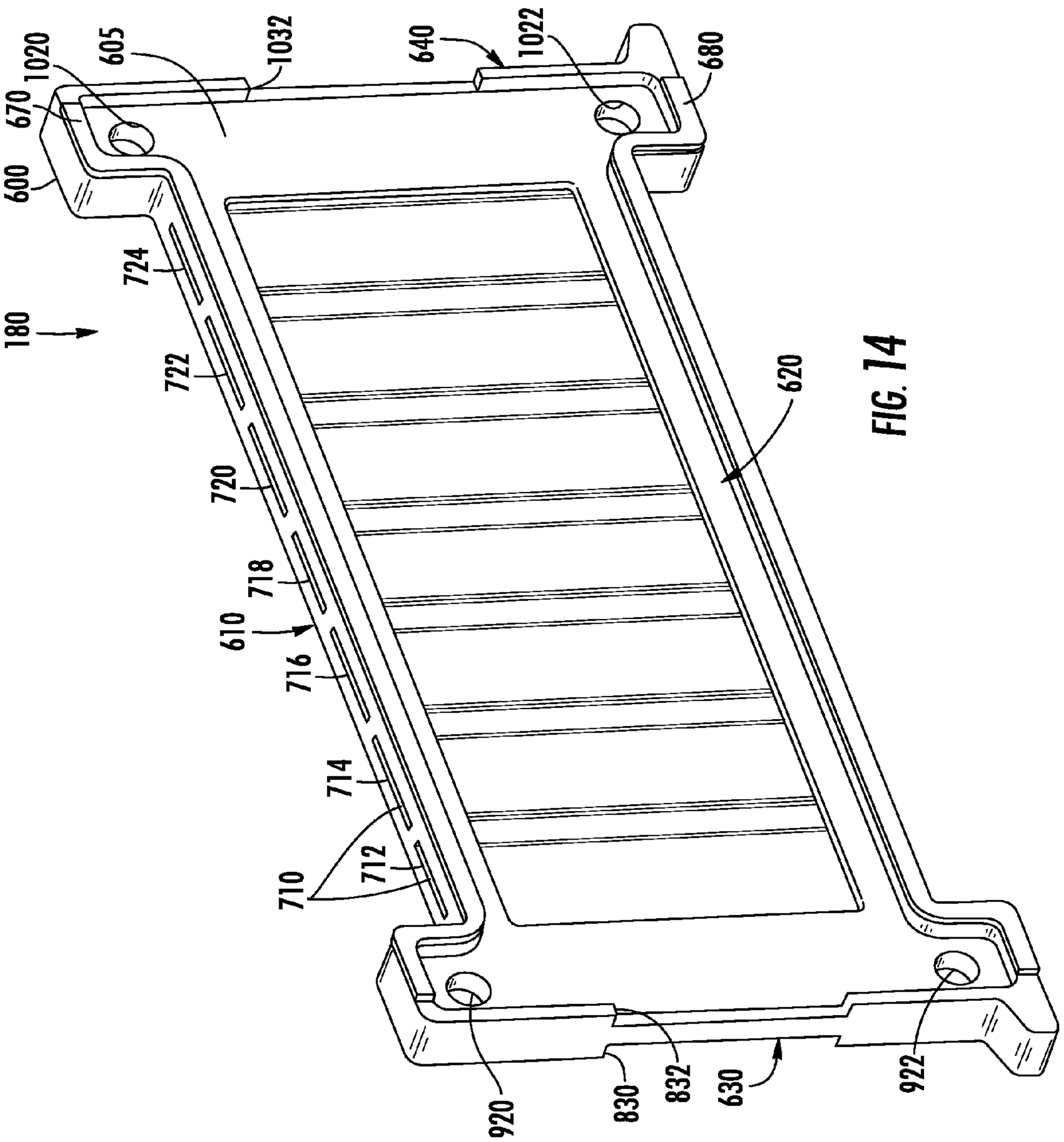

1020
605
1032
640
1022
680
670
600
724
180
722
720
718
610
716
714
712
710
620
920
830
832
630
922

FIG. 14

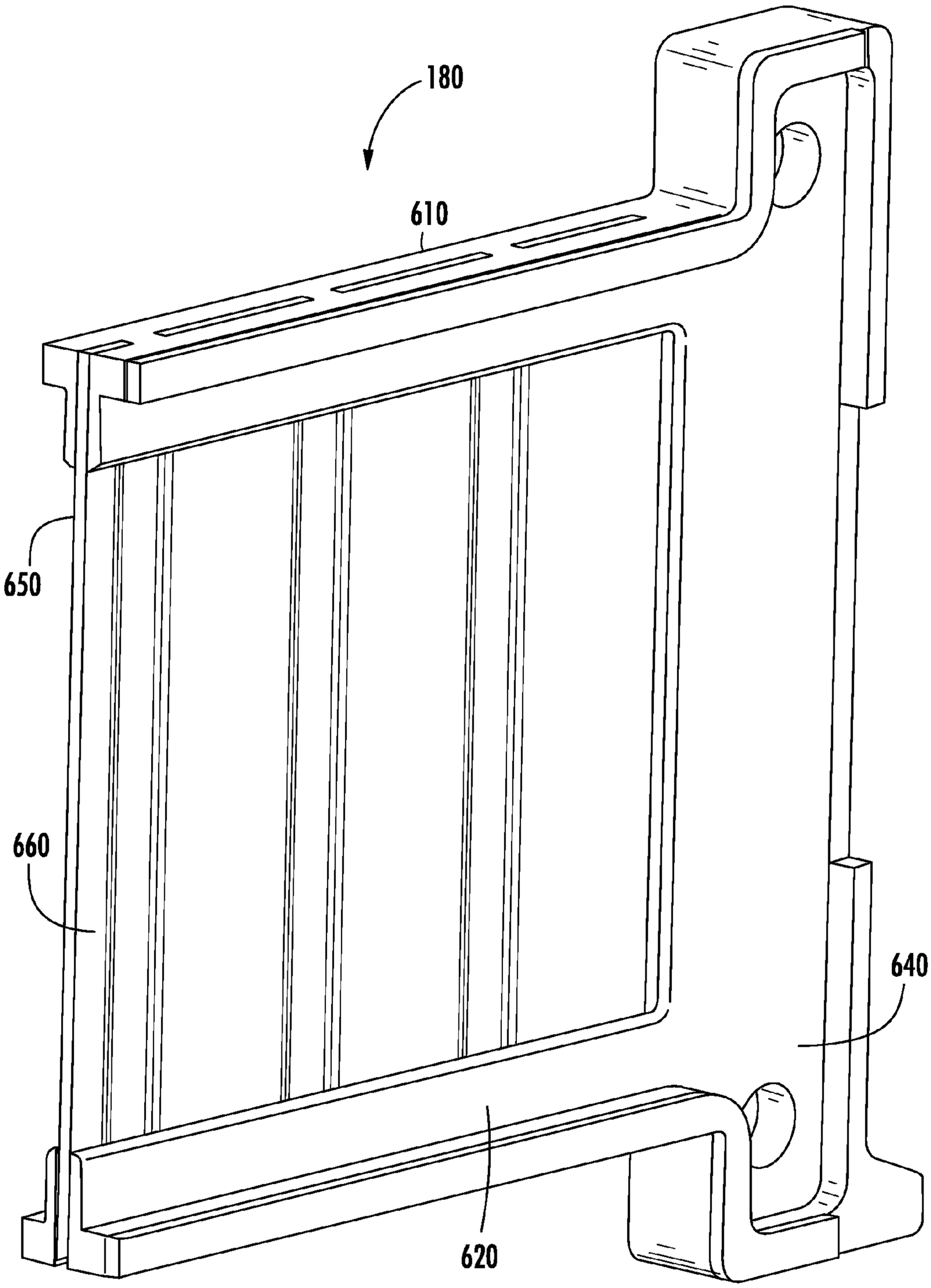


FIG. 15

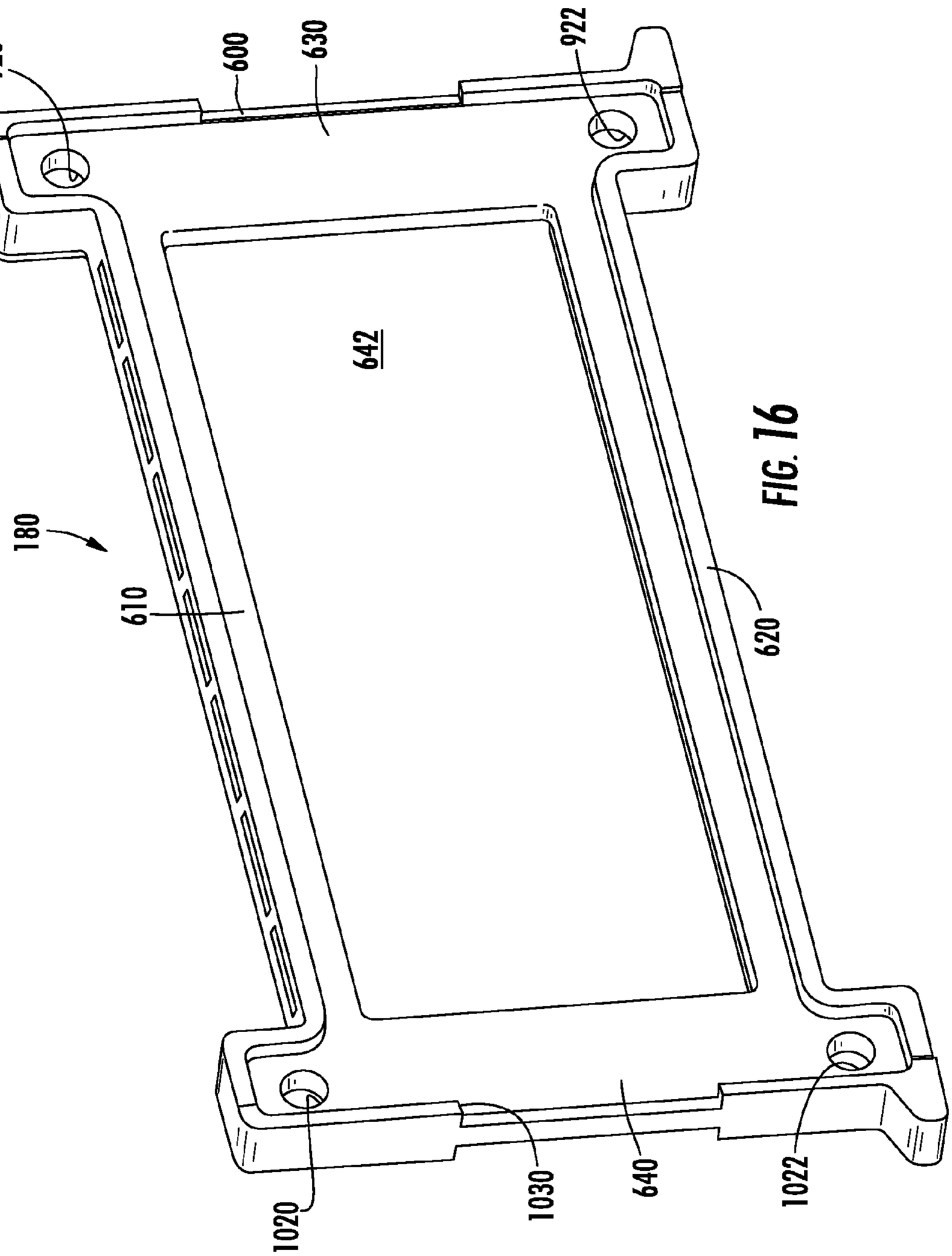


FIG. 16

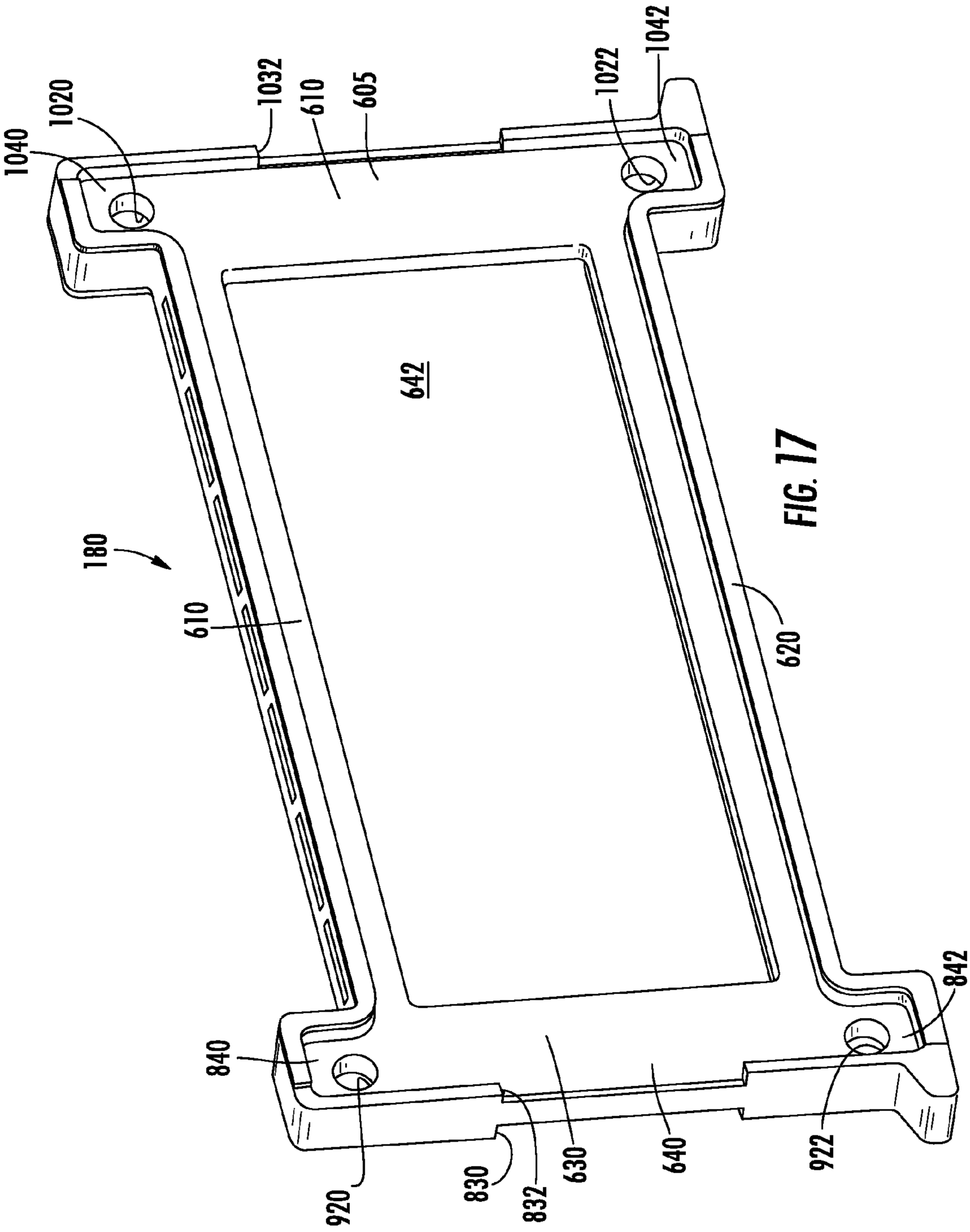

1042
1022
1032
610
605
1020
1040
642
180
610
620
840
842
920
830
832
630
640
922

FIG. 17

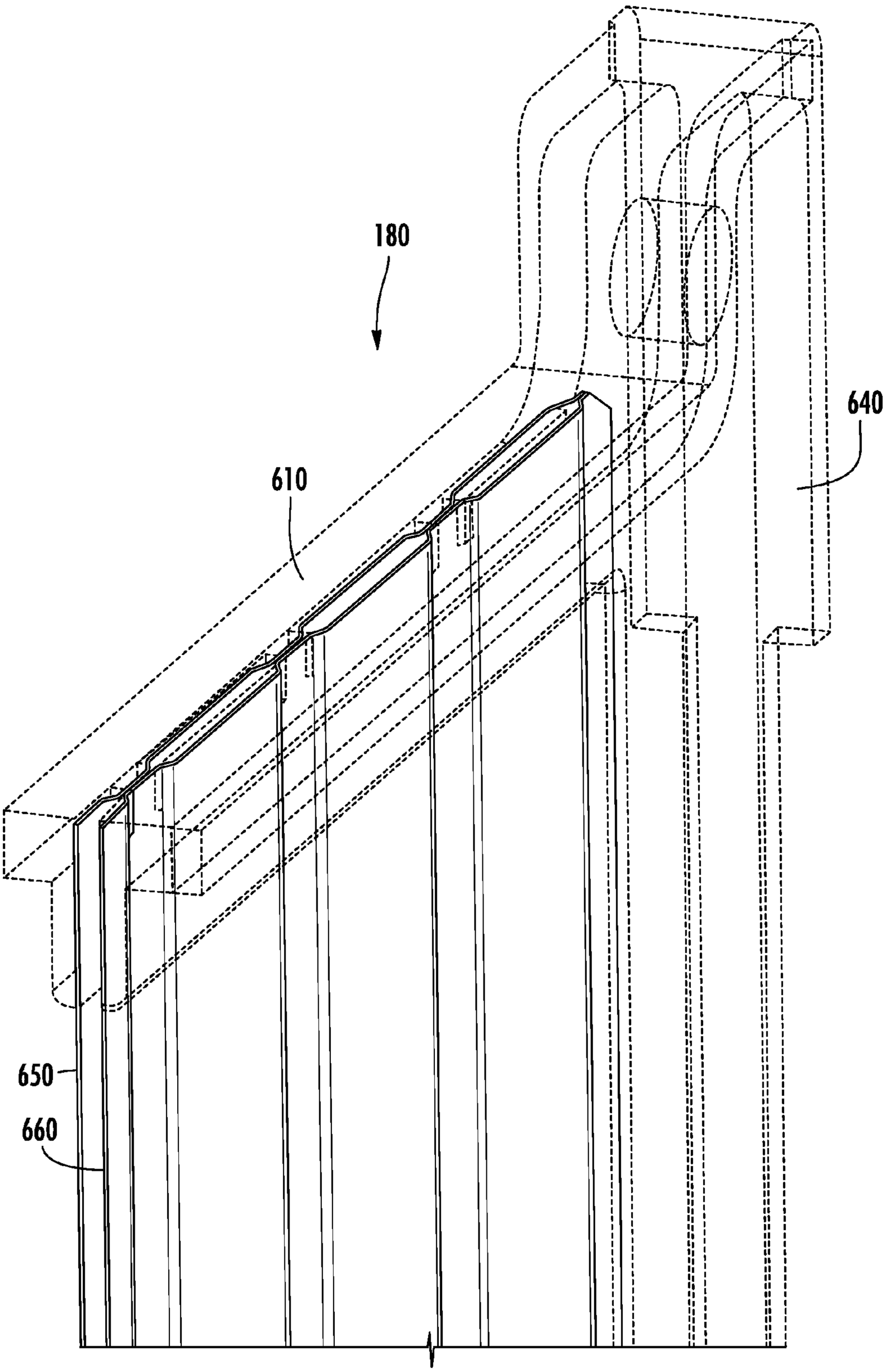


FIG. 18

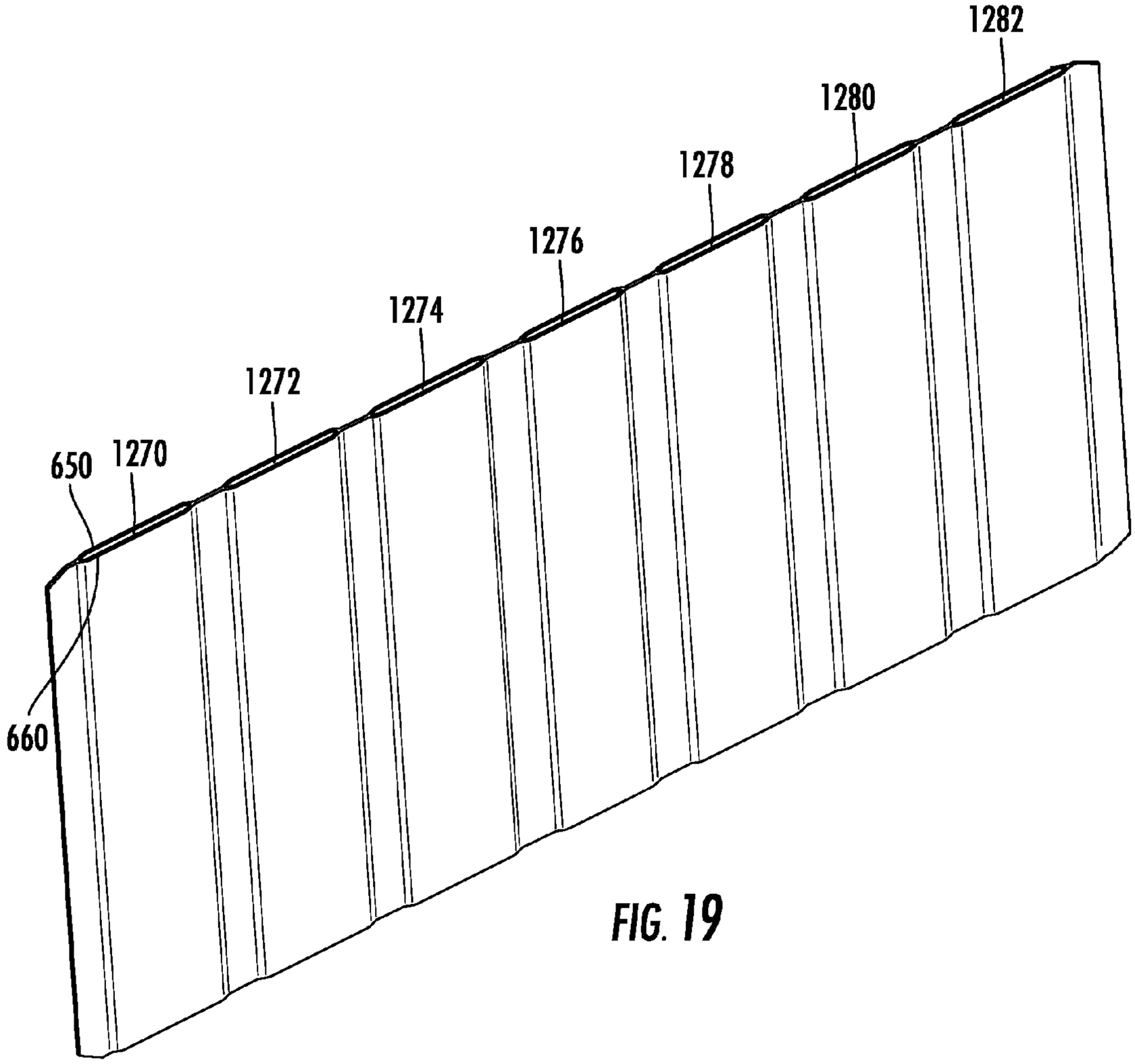


FIG. 19

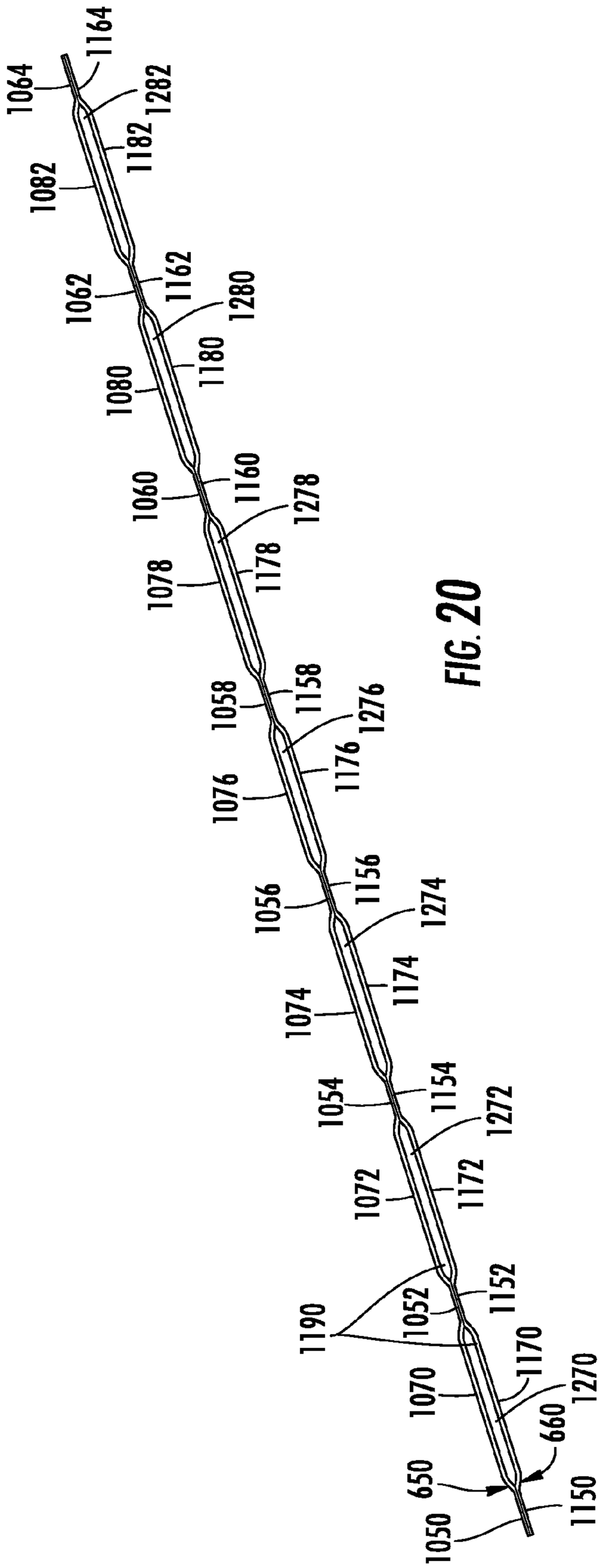

1164
1064
1282
1182
1082
1162
1062
1280
1180
1080
1160
1060
1278
1178
1078
1158
1058
1276
1176
1076
1156
1056
1274
1174
1074
1154
1054
1272
1172
1072
1152
1052
1190
1170
1070
1270
660
650
1150
1050

FIG. 20

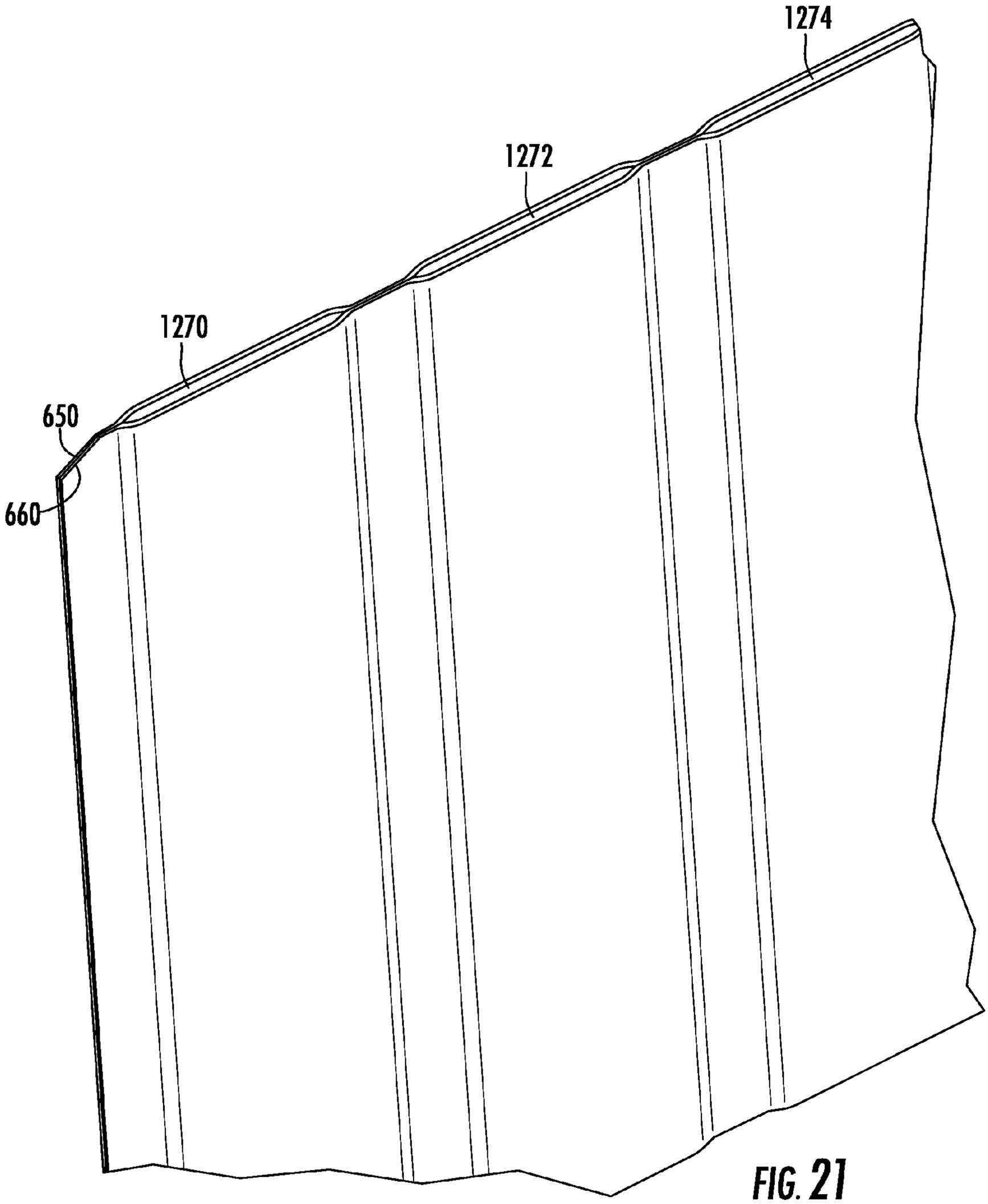


FIG. 21

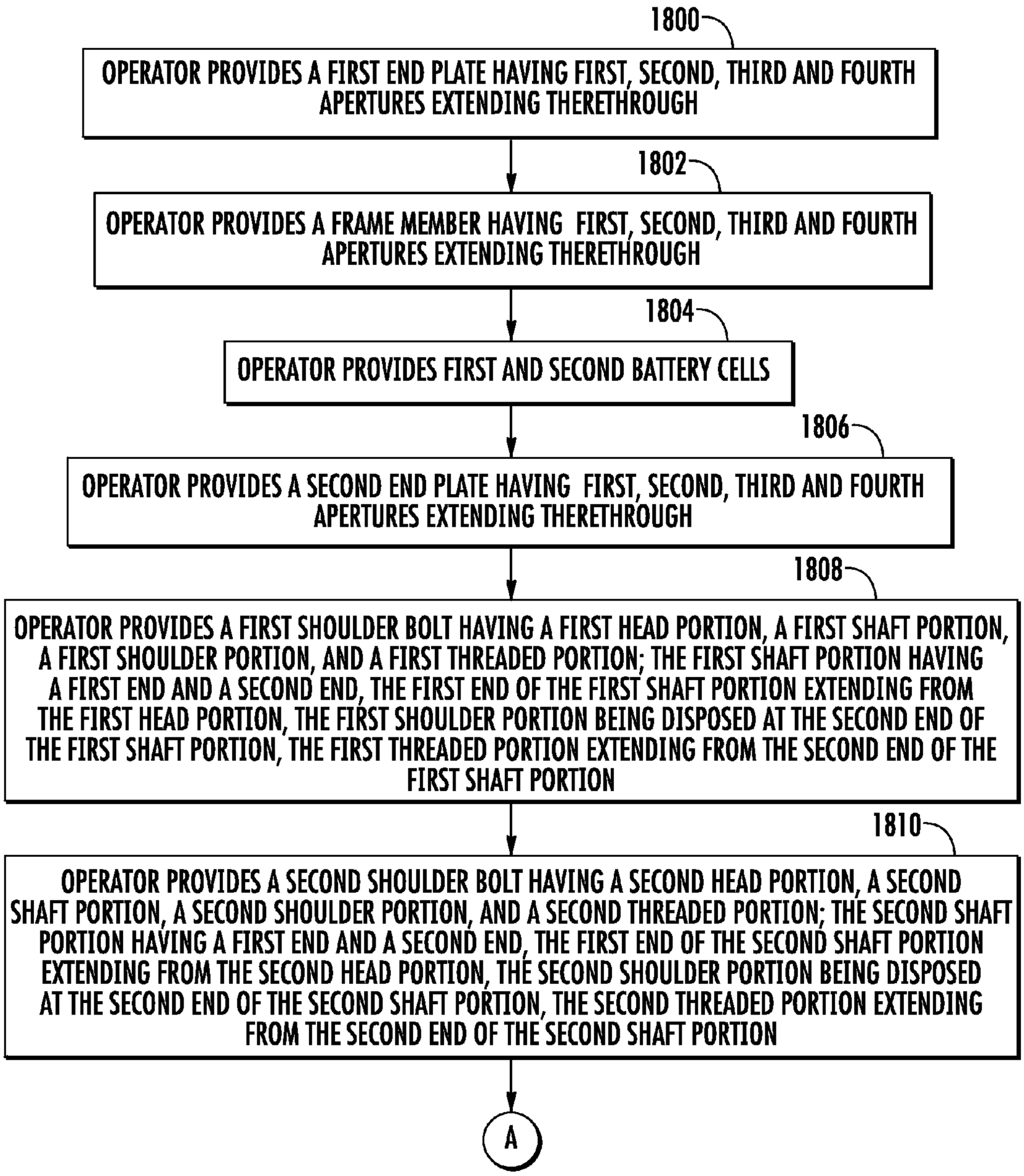

1800
OPERATOR PROVIDES A FIRST END PLATE HAVING FIRST, SECOND, THIRD AND FOURTH APERTURES EXTENDING THERETHROUGH
1802
OPERATOR PROVIDES A FRAME MEMBER HAVING FIRST, SECOND, THIRD AND FOURTH APERTURES EXTENDING THERETHROUGH
1804
OPERATOR PROVIDES FIRST AND SECOND BATTERY CELLS
1806
OPERATOR PROVIDES A SECOND END PLATE HAVING FIRST, SECOND, THIRD AND FOURTH APERTURES EXTENDING THERETHROUGH
1808
OPERATOR PROVIDES A FIRST SHOULDER BOLT HAVING A FIRST HEAD PORTION, A FIRST SHAFT PORTION, A FIRST SHOULDER PORTION, AND A FIRST THREADED PORTION; THE FIRST SHAFT PORTION HAVING A FIRST END AND A SECOND END, THE FIRST END OF THE FIRST SHAFT PORTION EXTENDING FROM THE FIRST HEAD PORTION, THE FIRST SHOULDER PORTION BEING DISPOSED AT THE SECOND END OF THE FIRST SHAFT PORTION, THE FIRST THREADED PORTION EXTENDING FROM THE SECOND END OF THE FIRST SHAFT PORTION
1810
OPERATOR PROVIDES A SECOND SHOULDER BOLT HAVING A SECOND HEAD PORTION, A SECOND SHAFT PORTION, A SECOND SHOULDER PORTION, AND A SECOND THREADED PORTION; THE SECOND SHAFT PORTION HAVING A FIRST END AND A SECOND END, THE FIRST END OF THE SECOND SHAFT PORTION EXTENDING FROM THE SECOND HEAD PORTION, THE SECOND SHOULDER PORTION BEING DISPOSED AT THE SECOND END OF THE SECOND SHAFT PORTION, THE SECOND THREADED PORTION EXTENDING FROM THE SECOND END OF THE SECOND SHAFT PORTION
A

FIG. 22

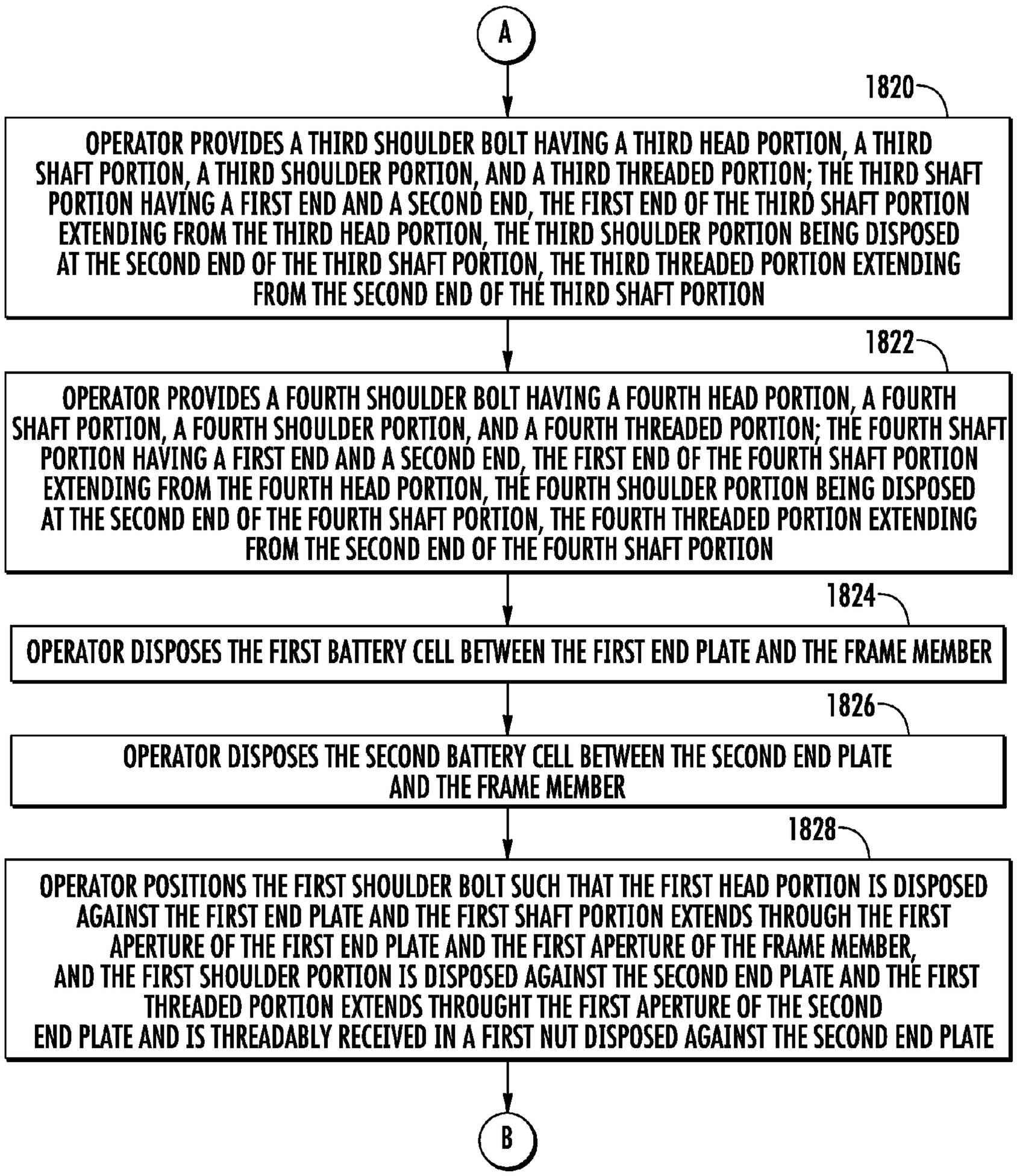

A
1820
OPERATOR PROVIDES A THIRD SHOULDER BOLT HAVING A THIRD HEAD PORTION, A THIRD SHAFT PORTION, A THIRD SHOULDER PORTION, AND A THIRD THREADED PORTION; THE THIRD SHAFT PORTION HAVING A FIRST END AND A SECOND END, THE FIRST END OF THE THIRD SHAFT PORTION EXTENDING FROM THE THIRD HEAD PORTION, THE THIRD SHOULDER PORTION BEING DISPOSED AT THE SECOND END OF THE THIRD SHAFT PORTION, THE THIRD THREADED PORTION EXTENDING FROM THE SECOND END OF THE THIRD SHAFT PORTION
1822
OPERATOR PROVIDES A FOURTH SHOULDER BOLT HAVING A FOURTH HEAD PORTION, A FOURTH SHAFT PORTION, A FOURTH SHOULDER PORTION, AND A FOURTH THREADED PORTION; THE FOURTH SHAFT PORTION HAVING A FIRST END AND A SECOND END, THE FIRST END OF THE FOURTH SHAFT PORTION EXTENDING FROM THE FOURTH HEAD PORTION, THE FOURTH SHOULDER PORTION BEING DISPOSED AT THE SECOND END OF THE FOURTH SHAFT PORTION, THE FOURTH THREADED PORTION EXTENDING FROM THE SECOND END OF THE FOURTH SHAFT PORTION
1824
OPERATOR DISPOSES THE FIRST BATTERY CELL BETWEEN THE FIRST END PLATE AND THE FRAME MEMBER
1826
OPERATOR DISPOSES THE SECOND BATTERY CELL BETWEEN THE SECOND END PLATE AND THE FRAME MEMBER
1828
OPERATOR POSITIONS THE FIRST SHOULDER BOLT SUCH THAT THE FIRST HEAD PORTION IS DISPOSED AGAINST THE FIRST END PLATE AND THE FIRST SHAFT PORTION EXTENDS THROUGH THE FIRST APERTURE OF THE FIRST END PLATE AND THE FIRST APERTURE OF THE FRAME MEMBER, AND THE FIRST SHOULDER PORTION IS DISPOSED AGAINST THE SECOND END PLATE AND THE FIRST THREADED PORTION EXTENDS THROUGHT THE FIRST APERTURE OF THE SECOND END PLATE AND IS THREADABLY RECEIVED IN A FIRST NUT DISPOSED AGAINST THE SECOND END PLATE
B

FIG. 23

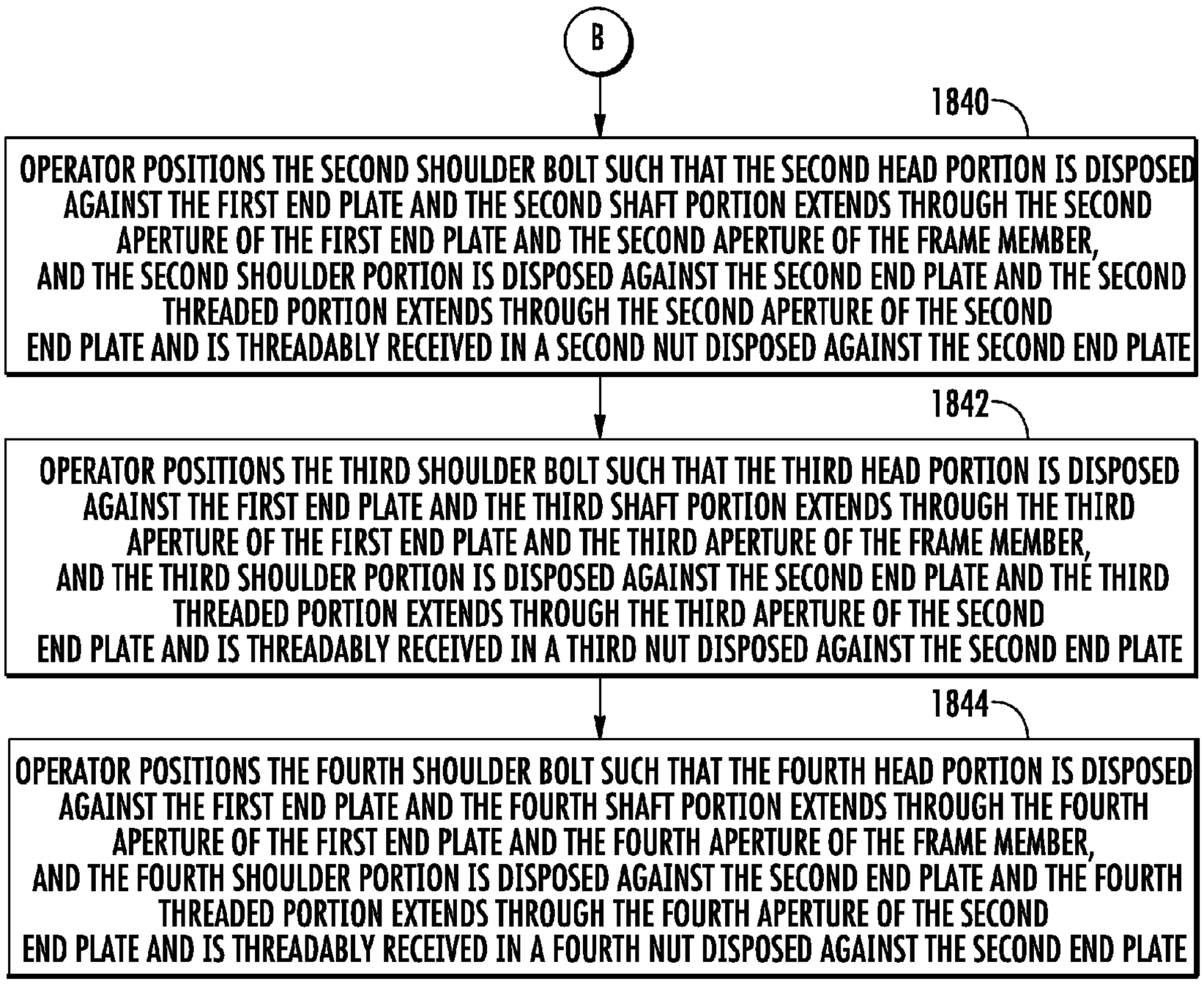

B
1840
OPERATOR POSITIONS THE SECOND SHOULDER BOLT SUCH THAT THE SECOND HEAD PORTION IS DISPOSED AGAINST THE FIRST END PLATE AND THE SECOND SHAFT PORTION EXTENDS THROUGH THE SECOND APERTURE OF THE FIRST END PLATE AND THE SECOND APERTURE OF THE FRAME MEMBER, AND THE SECOND SHOULDER PORTION IS DISPOSED AGAINST THE SECOND END PLATE AND THE SECOND THREADED PORTION EXTENDS THROUGH THE SECOND APERTURE OF THE SECOND END PLATE AND IS THREADABLY RECEIVED IN A SECOND NUT DISPOSED AGAINST THE SECOND END PLATE
1842
OPERATOR POSITIONS THE THIRD SHOULDER BOLT SUCH THAT THE THIRD HEAD PORTION IS DISPOSED AGAINST THE FIRST END PLATE AND THE THIRD SHAFT PORTION EXTENDS THROUGH THE THIRD APERTURE OF THE FIRST END PLATE AND THE THIRD APERTURE OF THE FRAME MEMBER, AND THE THIRD SHOULDER PORTION IS DISPOSED AGAINST THE SECOND END PLATE AND THE THIRD THREADED PORTION EXTENDS THROUGH THE THIRD APERTURE OF THE SECOND END PLATE AND IS THREADABLY RECEIVED IN A THIRD NUT DISPOSED AGAINST THE SECOND END PLATE
1844
OPERATOR POSITIONS THE FOURTH SHOULDER BOLT SUCH THAT THE FOURTH HEAD PORTION IS DISPOSED AGAINST THE FIRST END PLATE AND THE FOURTH SHAFT PORTION EXTENDS THROUGH THE FOURTH APERTURE OF THE FIRST END PLATE AND THE FOURTH APERTURE OF THE FRAME MEMBER, AND THE FOURTH SHOULDER PORTION IS DISPOSED AGAINST THE SECOND END PLATE AND THE FOURTH THREADED PORTION EXTENDS THROUGH THE FOURTH APERTURE OF THE SECOND END PLATE AND IS THREADABLY RECEIVED IN A FOURTH NUT DISPOSED AGAINST THE SECOND END PLATE

FIG. 24

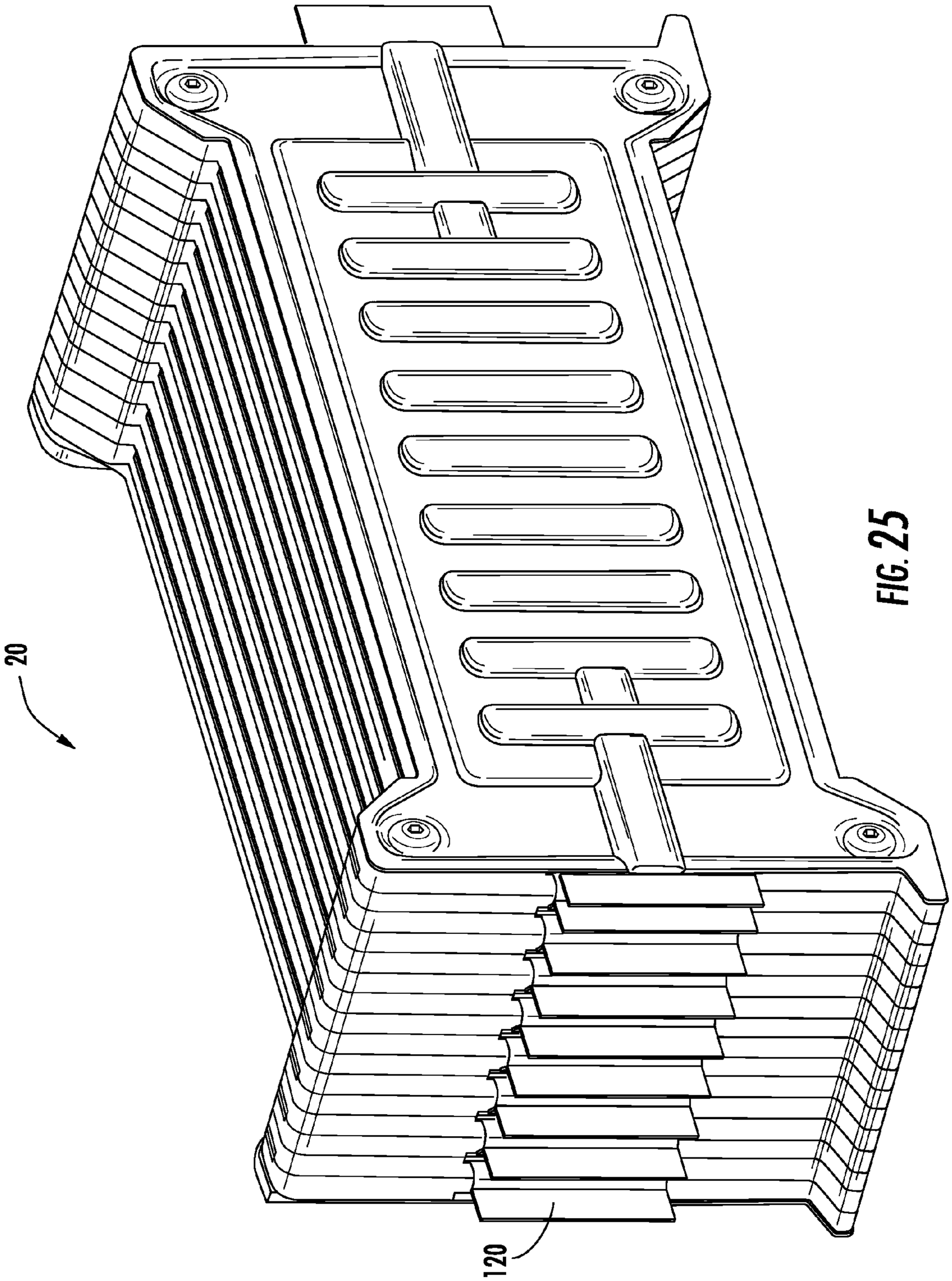


FIG. 25

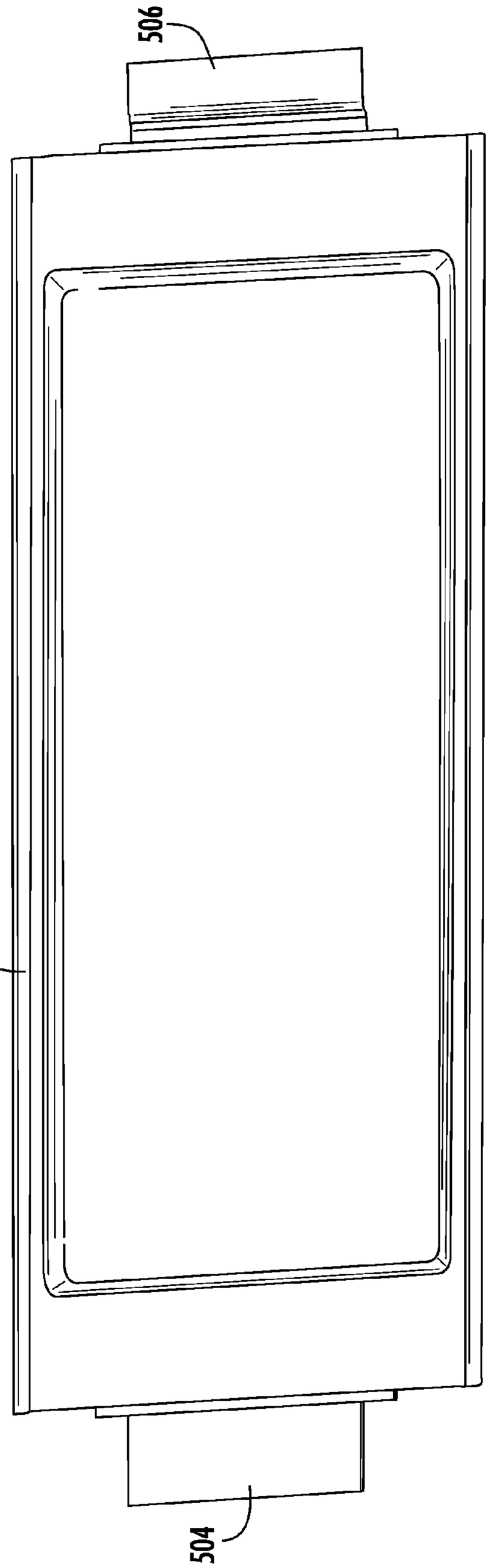


FIG. 26

BATTERY MODULE AND METHOD FOR ASSEMBLING THE BATTERY MODULE

BACKGROUND

The inventors herein have recognized a need for an improved battery module and a method for assembling the battery module.

SUMMARY

A battery module in accordance with an exemplary embodiment is provided. The battery module includes a first end plate having first, second, third and fourth apertures extending therethrough. The battery module further includes a frame member having first, second, third, and fourth apertures extending therethrough. The battery module further includes a first battery cell disposed between the first end plate and the frame member. The battery module further includes a second end plate having first, second, third and fourth apertures extending therethrough. The battery module further includes a second battery cell disposed between the second end plate and the frame member. The battery module further includes a first shoulder bolt having a first head portion, a first shaft portion, a first shoulder portion, and a first threaded portion. The first shaft portion has a first end and a second end. The first end of the first shaft portion extends from the first head portion. The first shoulder portion is disposed at the second end of the first shaft portion. The first threaded portion extends from the second end of the first shaft portion. The first shoulder bolt is disposed such that the first head portion is disposed against the first end plate and the first shaft portion extends through the first aperture of the first end plate and the first aperture of the frame member, and the first shoulder portion is disposed against the second end plate and the first threaded portion extends through the first aperture of the second end plate and is threadably received in a first nut disposed against the second end plate.

A method of assembling a battery module in accordance with another exemplary embodiment is provided. The method includes providing a first end plate having first, second, third and fourth apertures extending therethrough. The method further includes providing a frame member having first, second, third, and fourth apertures extending therethrough. The method further includes providing first and second battery cells. The method further includes providing a second end plate having first, second, third and fourth apertures extending therethrough. The method further includes providing a first shoulder bolt having a first head portion, a first shaft portion, a first shoulder portion, and a first threaded portion. The first shaft portion has a first end and a second end. The first end of the first shaft portion extends from the first head portion. The first shoulder portion is disposed at the second end of the first shaft portion. The first threaded portion extends from the second end of the first shaft portion. The method further includes disposing the first battery cell between the first end plate and the frame member. The method further includes disposing the second battery cell between the second end plate and the frame member. The method further includes positioning the first shoulder bolt such that the first head portion is disposed against the first end plate and the first shaft portion extends through the first aperture of the first end plate and the first aperture of the frame member, and the first shoulder portion is disposed against the second end plate and the first threaded portion extends through the first aperture of the second end plate and is threadably received in a first nut disposed against the second end plate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic of a battery module in accordance with an exemplary embodiment;

FIG. **2** is another schematic of the battery module of FIG. **1**;

FIG. **3** is a block diagram of a battery system utilizing the battery module of FIG. **1**;

FIG. **4** is a cross-sectional schematic of the battery module of FIG. **1**;

FIG. **5** is a schematic illustrating a top view of the battery module of FIG. **1**;

FIG. **6** is a schematic illustrating a bottom view of the battery module of FIG. **1**;

FIG. **7** is a cross-sectional schematic of the battery module of FIG. **1**;

FIG. **8** is an enlarged cross-sectional schematic of a portion of the battery module of FIG. **1**;

FIG. **9** is another cross-sectional schematic of the battery module of FIG. **1**;

FIG. **10** is another cross-sectional schematic of the battery module of FIG. **1**;

FIG. **11** is an enlarged cross-sectional schematic of a portion of the battery module of FIG. **1**;

FIG. **12** is another enlarged cross-sectional schematic of a portion of the battery module of FIG. **1**;

FIG. **13** is a schematic of a portion of the battery module of FIG. **1** illustrating electrical terminals extending therefrom;

FIG. **14** is a schematic of a frame member utilized in the battery module of FIG. **1**;

FIG. **15** is a cross-sectional schematic of the frame member of FIG. **14**;

FIG. **16** is a schematic of a portion of the frame member of FIG. **14**;

FIG. **17** is another schematic of a portion of the frame member of FIG. **14**;

FIG. **18** is a cross-sectional schematic of a portion of the frame member of FIG. **14**;

FIG. **19** is a schematic of the first and second thermally conductive plates utilized to form flow channels in the frame member of FIG. **14**;

FIG. **20** is a cross-sectional schematic of the first and second thermally conductive plates of FIG. **19**;

FIG. **21** is an enlarged cross-sectional schematic of a portion of the first and second thermally conductive plates of FIG. **19**;

FIGS. **22-24** are flowcharts a method for assembling the battery module of FIG. **1** in accordance with another exemplary embodiment;

FIG. **25** is another schematic of the battery module of FIG. **1** having electrical terminals; and

FIG. **26** is a schematic of a battery cell utilized in the battery module of FIG. **1**.

DETAILED DESCRIPTION

Referring to FIGS. **1-4**, a battery system **10** having a battery module **20**, an air cooling system **30**, and conduits **40**, **42** is illustrated. The air cooling system **30** moves air through the conduit **40** and the battery module **20** and then through the conduit **42** for cooling battery cells within the battery module **20**.

Referring to FIGS. **3-10**, the battery module **20** includes end plates **100**, **102**, battery cells **120**, **122**, **124**, **126**, **128**,

130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, frame members 180, 182, 184, 186, 188, 190, 192, 194, first, second, third, and fourth shoulder bolts 220, 222, 224, 226, nuts 240, 242, 244, 246, and manifolds 260, 262.

Referring to FIGS. 7 and 9, the end plates 100, 102 are provided to hold the remaining components of the battery module 20 therebetween. In one exemplary embodiment, the end plates 100, 102 are constructed of steel. The end plate 100 includes apertures 320, 322, 324, 326 extending therethrough for receiving portions of shoulder bolts therethrough. The end plate 102 includes apertures 420, 422, 424, 426 extending therethrough for receiving portions of shoulder bolts therethrough.

Referring to FIGS. 7, 13, 25 and 26, the battery cells 120-150 have a substantially similar structure. Thus, only the structure of the battery cell 120 will be described in greater detail below. In one exemplary embodiment, the battery cells 120-150 are electrically coupled in series to one another. Further, in one exemplary embodiment, the battery cells 120-150 are lithium-ion battery cells. Of course, in alternative embodiments, the battery cells 120-150 could be other types of battery cells known to those skilled in the art. The battery cell 120 includes a body portion 502 and electrical terminals 504, 506 extending from opposite ends of the body portion 502.

Referring to FIGS. 4-6 and 14, the frame members 180-194 are provided to hold the battery cells therebetween and to allow air to flow through the frame members 180-194 to cool the battery cells.

The frame member 180 is disposed between the end plate 100 and the frame member 182. The battery cell 120 is disposed between the frame member 180 and the end plate 100. Also, the battery cells 122, 124 are disposed between the frame members 180, 182 and the body portions of the battery cells 122, 124 are surrounded by the frame members 180, 182.

The frame member 182 is disposed between the frame member 180 and the frame member 184. The battery cells 126, 128 are disposed between the frame members 182, 184 and the body portions of the battery cells 126, 128 are surrounded by the frame members 182, 184.

The frame member 184 is disposed between the frame member 182 and the frame member 186. The battery cells 130, 132 are disposed between the frame members 184, 186 and the body portions of the battery cells 130, 132 are surrounded by the frame members 184, 186.

The frame member 186 is disposed between the frame member 184 and the frame member 188. The battery cells 134, 136 are disposed between the frame members 186, 188 and the body portions of the battery cells 134, 136 are surrounded by the frame members 186, 188.

The frame member 188 is disposed between the frame member 186 and the frame member 190. The battery cells 138, 140 are disposed between the frame members 188, 190 and the body portions of the battery cells 138, 140 are surrounded by the frame members 188, 190.

The frame member 190 is disposed between the frame member 188 and the frame member 192. The battery cells 142, 144 are disposed between the frame members 190, 192 and the body portions of the battery cells 142, 144 are surrounded by the frame members 190, 192.

The frame member 192 is disposed between the frame member 190 and the frame member 194. The battery cells 146, 148 are disposed between the frame members 192, 194 and the body portions of the battery cells 146, 148 are surrounded by the frame members 192, 194.

The frame member 194 is disposed between the frame member 192 and the end plate 102. The battery cell 150 is disposed between the frame member 194 and the end plate 102 and the body portion of the battery cell 150 is surrounded by the frame member 194 and the end plate 102.

The frame members 180-194 have an identical structure and only the structure of the frame member 180 will be described in greater detail below. Referring to FIGS. 5, 6 and 14-17, the frame member 180 includes first and second sides 600, 605, first, second, third, and fourth peripheral walls 610, 620, 630, 640, first and second thermally conductive plates 650, 660, and first and second elastomeric sealing members 670, 680. In one exemplary embodiment, the first, second, third and fourth peripheral walls 610, 620, 630, 640 define a substantially rectangular ring-shaped frame and are centered symmetrically about a plane 641 extending through the walls 610, 620, 630, 640. The first and second peripheral walls 610, 620 are substantially parallel to one another and are disposed between and coupled to the third and fourth peripheral walls 630, 640. The third and fourth peripheral wall 630, 640 are substantially parallel to one another and are substantially perpendicular to the first and second peripheral walls 610, 620. The first, second, third and fourth peripheral walls 610, 620, 630, 640 define an open interior region 642 (shown in FIG. 16) therebetween. In one exemplary embodiment, the first, second, third, and fourth peripheral walls 610, 620, 630, 640 are constructed of plastic.

The first peripheral wall 610 includes a plurality of apertures 710 extending therethrough. The plurality of apertures 710 include apertures 712, 714, 716, 718, 720, 722, 724. The plurality of apertures 710 are configured to receive air flowing therethrough for cooling battery cells.

The second peripheral wall 620 includes a plurality of apertures 810 extending therethrough. The plurality of apertures 810 include apertures 812, 814, 816, 818, 820, 822, 824. The plurality of apertures 810 are configured to receive air flowing therethrough for cooling battery cells.

The third peripheral wall 630 includes an outlet 830 (e.g., a groove) extending into the first side 600, and an outlet 832 (e.g., a groove) extending into the second side 605. Alternatively, the outlets 830, 832, could be apertures extending through the third peripheral wall 630. The outlets 830, 832 are configured to receive an electrical terminal 504 and another electrical terminal, respectively, of the battery cells 120, 122 therethrough. Further, the outlets 830, 832 are configured to route any gases from the battery cells 120, 122 past the associated electrical terminals to outside of the frame member 180 if the battery cells 120, 122 output gases therefrom. The third peripheral wall 630 further includes peripheral corner regions 840, 842 having apertures 920, 922 respectively, extending therethrough. The apertures 920, 922 are configured to receive portions of the shoulder bolts 220, 222, respectively, therethrough.

The fourth peripheral wall 640 includes an outlet 1030 (e.g., a groove) extending into the first side 600, and an outlet 1032 (e.g., a groove) extending into the second side 605. Alternatively, the outlets 1030, 1032, could be apertures extending through the fourth peripheral wall 640. The outlets 1030, 1032 are configured to receive an electrical terminal 506 and another electrical terminal, respectively, of the battery cells 120, 122 therethrough. Further, the outlets 1030, 1032 are configured to route any gases from the battery cells 120, 122 past the associated electrical terminals to outside of the frame member 180 if the battery cells 120, 122 output gases therefrom. The fourth peripheral wall 640 further includes peripheral corner regions 1040, 1042 having apertures 1020, 1022 respectively, extending therethrough. The

apertures **1020**, **1022** are configured to receive portions of the shoulder bolts **224**, **226**, respectively, therethrough.

Referring to FIGS. **4** and **18-21**, the first and second thermally conductive plates **650**, **660** are configured to conduct heat energy away from adjacent battery cells into air flowing between the plates **650**, **660**. In one exemplary embodiment, the first and second thermally conductive plates **650**, **660** are constructed of steel and have corrugated cross-sectional profiles which define a plurality of flow channels therebetween. Of course, in alternative embodiments, other thermally conductive materials known to those skilled in the art could be utilized to construct the plates **650**, **660**. The first and second thermally conductive plates **650**, **660** are fixedly coupled together via weld joints. In one exemplary embodiment, the first, second, third, and fourth peripheral walls **610**, **620**, **630**, **640** are injected-molded around portions of the first and second thermally conductive plates **650**, **660**.

The first thermally conductive plate **650** is coupled to the first, second, third and fourth peripheral walls **610**, **620**, **630**, **640** to enclose the open interior region **642** proximate to the first side **600** of the frame member **180**. The first thermally conductive plate **650** is disposed against the battery cell **120**. An area of a side of the first thermally conductive plate **650** is substantially equal to an area of a side of a body portion of the battery cell **120** adjacent to the first thermally conductive plate **650**. The first thermally conductive plate **650** includes tread portions **1050**, **1052**, **1054**, **1056**, **1058**, **1060**, **1062**, **1064** and ridge portions **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, **1084**.

The second thermally conductive plate **660** is coupled to the first, second, third and fourth peripheral walls **610**, **620**, **630**, **640** to enclose the open interior region **642** proximate to the second side **605** of the frame member **180**. The second thermally conductive plate **660** is disposed against the battery cell **122**. An area of a side of the second thermally conductive plate **660** is substantially equal to an area of a side of a body portion of the battery cell **122** adjacent to the second thermally conductive plate **660**. The second thermally conductive plate **660** includes tread portions **1150**, **1152**, **1154**, **1156**, **1158**, **1160**, **1162**, **1164** and ridge portions **1170**, **1172**, **1174**, **1176**, **1178**, **1180**, **1182**, **1184**. The tread portions **1150**, **1152**, **1154**, **1156**, **1158**, **1160**, **1162**, **1164** of the second thermally conductive plate **660** are disposed against the tread portions **1050**, **1052**, **1054**, **1056**, **1058**, **1060**, **1062**, **1064**, respectively, of the first thermally conductive plate **650**.

The ridge portions **1170**, **1172**, **1174**, **1176**, **1178**, **1180**, **1182**, **1184** of the second thermally conductive plate **660** are disposed opposite to the ridge portions **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, **1084**, respectively, of the first thermally conductive plate **650**, to form flow channels **1270**, **1272**, **1274**, **1276**, **1278**, **1280**, **1282**, respectfully therebetween. The plurality of flow channels **1270-1282** comprise a plurality of flow channels **1190**.

Referring to FIGS. **5**, **6**, **11**, **12** and **20**, the apertures **712**, **714**, **716**, **718**, **720**, **722**, **724** in the first peripheral wall **610** of the frame member **180** fluidly communicate with a first end of the flow channels **1270**, **1272**, **1274**, **1276**, **1278**, **1280**, **1282**, respectively. Further, the apertures **812**, **714**, **816**, **818**, **820**, **822**, **824** in the second peripheral wall **620** of the frame member **180** fluidly communicate with a second end of the flow channels **1270**, **1272**, **1274**, **1276**, **1278**, **1280**, **1282**, respectively. During operation, air flows through the apertures **712**, **714**, **716**, **718**, **720**, **722**, **724** and through the flow channels **1270**, **1272**, **1274**, **1276**, **1278**, **1280**, **1282**, respectively and further through the apertures **812**, **714**, **816**, **818**, **820**, **822**, **824**, respectively, to extract energy from battery cells **120**, **122** adjacent to the first and second thermally conductive plates **650**, **660**, respectively.

Referring to FIGS. **4** and **14**, the frame member **180** includes first and second elastomeric sealing members **670**, **680** disposed on the first and second peripheral walls **610**, **620**, respectively. The first and second elastomeric sealing members **670**, **680** direct any gases output by the battery cells **122**, **124** to be directed toward the outlets **832**, **1032** which then exit the outlets **832**, **1032** to outside of the frame member **180** and the battery module **20**. Thus, a flow path of any gases output by the battery cells is isolated and separate from the plurality of flow paths **1190** through the first and second thermally conductive plates **650**, **660**.

Referring to FIGS. **2**, **7** and **9**, the first, second, third, and fourth shoulder bolts **220**, **222**, **224**, **226** are provided to couple the end plate **100**, the frame members **180-194**, and the end plate **102** together. Also, a length of a shaft portion of each of shoulder bolts sets a distance between the end plates **100**, **102** and thus a longitudinal force applied to each of the frame members **180-194**.

The first shoulder bolt **220** includes a head portion **1400**, a shaft portion **1410**, a shoulder portion **1420**, and a threaded portion **1430**. The shaft portion **1410** has a first end **1412** and a second end **1414**. The first end **1412** extends from the head portion **1400**. The shoulder portion **1420** is disposed at the second end **1414** of the shaft portion **1410**. The threaded portion **1430** extends from the second end **1414** of the shaft portion **1410**.

The first shoulder bolt **220** is disposed such that the head portion **1400** is disposed against the first end plate **100** and the shaft portion **1410** extends through the aperture **320** of the first end plate **100** and the aperture **920** of the frame member **180** and each respective adjacent aperture in the frame members **182-194**, and the shoulder portion **1420** is disposed against the second end plate **102** and the threaded portion **1430** extends through the aperture **420** of the second end plate **102** and is threadably received in a nut **240** disposed against the second end plate **102**.

The second shoulder bolt **222** includes a head portion **1500**, a shaft portion **1510**, a shoulder portion **1520**, and a threaded portion **1530**. The shaft portion **1510** has a first end **1512** and a second end **1514**. The first end **1512** extends from the head portion **1500**. The shoulder portion **1520** is disposed at the second end **1514** of the shaft portion **1510**. The threaded portion **1530** extends from the second end **1514** of the shaft portion **1510**.

The second shoulder bolt **222** is disposed such that the head portion **1500** is disposed against the first end plate **100** and the shaft portion **1510** extends through the aperture **322** of the first end plate **100** and the aperture **922** of the frame member **180** and each respective adjacent aperture in the frame members **182-194**, and the shoulder portion **1520** is disposed against the second end plate **102** and the threaded portion **1530** extends through the aperture **422** of the second end plate **102** and is threadably received in a nut **242** disposed against the second end plate **102**.

The third shoulder bolt **224** includes a head portion **1600**, a shaft portion **1610**, a shoulder portion **1620**, and a threaded portion **1630**. The shaft portion **1610** has a first end **1612** and a second end **1614**. The first end **1612** extends from the head portion **1600**. The shoulder portion **1620** is disposed at the second end **1614** of the shaft portion **1610**. The threaded portion **1630** extends from the second end **1614** of the shaft portion **1610**.

The third shoulder bolt **224** is disposed such that the head portion **1600** is disposed against the first end plate **100** and the shaft portion **1660** extends through the aperture **324** of the

first end plate **100** and the aperture **1020** of the frame member **180** and each respective adjacent aperture in the frame members **182-194**, and the shoulder portion **1620** is disposed against the second end plate **102** and the threaded portion **1630** extends through the aperture **424** of the second end plate **102** and is threadably received in a nut **244** disposed against the second end plate **102**.

The fourth shoulder bolt **226** includes a head portion **1700**, a shaft portion **1710**, a shoulder portion **1720**, and a threaded portion **1730**. The shaft portion **1710** has a first end **1712** and a second end **1714**. The first end **1712** extends from the head portion **1700**. The shoulder portion **1720** is disposed at the second end **1714** of the shaft portion **1710**. The threaded portion **1730** extends from the second end **1714** of the shaft portion **1710**.

The fourth shoulder bolt **226** is disposed such that the head portion **1700** is disposed against the first end plate **100** and the shaft portion **1760** extends through the aperture **326** of the first end plate **100** and the aperture **1022** of the frame member **180** and each respective adjacent aperture in the frame members **182-194**, and the shoulder portion **1720** is disposed against the second end plate **102** and the threaded portion **1730** extends through the aperture **426** of the second end plate **102** and is threadably received in a nut **246** disposed against the second end plate **102**.

Referring to FIGS. **3** and **4**, the manifold **260** is configured to route air from the conduit **40** into the apertures in the first peripheral walls (e.g., upper walls) of the frame members **180-194** which flows through the plurality of flow channels **1190** to the apertures in the second peripheral walls (e.g., lower walls) of the frame members **180-194**. The manifold **262** is configured to receive the air from the apertures in the second peripheral walls of the frame members **180-194** and to route the air into the conduit **42**. The conduit **42** routes the air to the air cooling system **30**.

Referring to FIGS. **7**, **9** and **22-24**, a flowchart of a method for assembling the battery module **20** in accordance with another exemplary embodiment is provided. For purposes of simplicity, the method will only describe the assembly process utilizing first and second battery cells and a single frame member. Of course, it should be understood that the method can be implemented utilizing a plurality of additional frame members and a plurality of additional battery cells.

At step **1800**, an operator provides the end plate **100** having the apertures **320**, **322**, **324**, **326** extending therethrough.

At step **1802**, the operator provides the frame member **180** having the apertures **920**, **922**, **1020**, **1022** extending therethrough.

At step **1804**, the operator provides the battery cells **120**, **122**.

At step **1806**, the operator provides the end plate **102** having the apertures **420**, **422**, **424**, **426** extending therethrough.

At step **1808**, the operator provides the first shoulder bolt **220** having the head portion **1400**, the shaft portion **1410**, the shoulder portion **1420**, and the threaded portion **1430**. The shaft portion **1410** has the first end **1412** and the second end **1414**. The first end **1412** of the shaft portion **1410** extends from the head portion **1400**. The shoulder portion **1420** is disposed at the second end **1414** of the shaft portion **1410**. The threaded portion **1430** extends from the second end of the shaft portion **1410**.

At step **1810**, the operator provides the second shoulder bolt **222** having the head portion **1500**, the shaft portion **1510**, the shoulder portion **1520**, and the threaded portion **1530**. The shaft portion **1510** has the first end **1512** and the second end **1514**. The first end of the shaft portion **1510** extends from the head portion **1500**. The shoulder portion **1520** is disposed at the second end **1514** of the shaft portion **1510**. The threaded portion **1530** extends from the second end **1514** of the shaft portion **1510**.

At step **1820**, the operator provides the shoulder bolt **224** having the head portion **1600**, the shaft portion **1610**, the shoulder portion **1620**, and the threaded portion **1630**. The shaft portion **1610** has the first end **1612** and the second end **1614**. The first end **1612** of the shaft portion **1610** extends from the head portion **1600**. The shoulder portion **1620** is disposed at the second end **1614** of the shaft portion **1610**. The threaded portion **1630** extends from the second end **1614** of the shaft portion **1610**.

At step **1822**, the operator provides the fourth shoulder bolt **226** having the head portion **1700**, the shaft portion **1710**, the shoulder portion **1720**, and the threaded portion **1730**. The shaft portion **1710** has the first end **1712** and the second end **1714**. The first end **1712** of the shaft portion **1710** extends from the head portion **1700**. The shoulder portion **1720** is disposed at the second end **1714** of the shaft portion **1710**. The threaded portion **1730** extends from the second end **1714** of the shaft portion **1710**.

At step **1824**, the operator disposes the battery cell **120** between the end plate **100** and the frame member **180**.

At step **1826**, the operator disposes the battery cell **122** between the end plate **102** and the frame member **180**.

At step **1828**, the operator positions the first shoulder bolt **220** such that the head portion **1400** is disposed against the end plate **100** and the shaft portion **1410** extends through the aperture **320** of the end plate **100** and the aperture **920** of the frame member **180**, and the shoulder portion **1420** is disposed against the end plate **102** and the threaded portion **1430** extends through the aperture **420** of the end plate **102** and is threadably received in the nut **240** disposed against the end plate **102**.

At step **1840**, the operator positions the second shoulder bolt **222** such that the head portion **1500** is disposed against the end plate **100** and the shaft portion **1510** extends through the aperture **322** of the end plate **100** and the aperture **922** of the frame member **180**, and the shoulder portion **1520** is disposed against the end plate **102** and the threaded portion **1530** extends through the aperture **422** of the end plate **102** and is threadably received in the nut **242** disposed against the end plate **102**.

At step **1842**, the operator positions the third shoulder bolt **224** such that the head portion **1600** is disposed against the end plate **100** and the shaft portion **1610** extends through the aperture **324** of the end plate **100** and the aperture **1020** of the frame member **180**, and the shoulder portion **1620** is disposed against the end plate **102** and the threaded portion **1630** extends through the aperture **424** of the end plate **102** and is threadably received in the nut **244** disposed against the end plate **102**.

At step **1844**, the operator positions the fourth shoulder bolt **226** such that the head portion **1700** is disposed against the end plate **100** and the shaft portion **1710** extends through the aperture **326** of the end plate **100** and the aperture **1022** of the frame member **180**, and the shoulder portion **1720** is disposed against the end plate **102** and the threaded portion **1730** extends through the aperture **426** of the end plate **102** and is threadably received in the nut **246** disposed against the end plate **102**.

The battery module **20** and the method for assembling the battery module **20** provide a substantial advantage over other battery modules and methods. In particular, the battery module **20** and method utilize shoulder bolts to couple end plates and frame members together such that the lengths of the shaft portions of the shoulder bolts set a distance between the end

plates and thus a longitudinal force applied to each of the frame members disposed between the end plates.

While the claimed invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the claimed invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the claimed invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the claimed invention is not to be seen as limited by the foregoing description.

What is claimed is:

1. A battery module, comprising:

a first end plate having first, second, third and fourth apertures extending therethrough;

a frame member having first, second, third, and fourth apertures extending therethrough;

a first battery cell disposed between the first end plate and the frame member;

a second end plate having first, second, third and fourth apertures extending therethrough, the second end plate further having a first side and a second side disposed opposite to the first side;

a second battery cell disposed between the second end plate and the frame member;

a first shoulder bolt having a first head portion, a first shaft portion, a first shoulder portion, and a first threaded portion; the first shaft portion having a first end and a second end, the first end of the first shaft portion extending from the first head portion, the first shoulder portion being disposed at the second end of the first shaft portion, the first threaded portion extending from the second end of the first shaft portion; and

the first shoulder bolt being disposed such that the first head portion is disposed against the first end plate and the first shaft portion extends through the first aperture of the first end plate and the first aperture of the frame member, and the first shoulder portion being disposed directly against and contacting the first side of the second end plate and the first threaded portion extending through the first aperture of the second end plate and being threadably received in a first nut, and the first nut being disposed directly against and contacting the second side of the second end plate.

2. The battery module of claim **1**, further comprising:

a second shoulder bolt having a second head portion, a second shaft portion, a second shoulder portion, and a second threaded portion; the second shaft portion having a first end and a second end, the first end of the second shaft portion extending from the second head portion, the second shoulder portion being disposed at the second end of the second shaft portion, the second threaded portion extending from the second end of the second shaft portion; and

the second shoulder bolt being disposed such that the second head portion is disposed against the first end plate and the second shaft portion extends through the second aperture of the first end plate and the second aperture of the frame member, and the second shoulder portion is disposed against the second end plate and the second threaded portion extends through the second aperture of the second end plate and is threadably received in a second nut disposed against the second end plate.

3. The battery module of claim **2**, further comprising:

a third shoulder bolt having a third head portion, a third shaft portion, a third shoulder portion, and a third threaded portion; the third shaft portion having a first end and a second end, the first end of the third shaft portion extending from the third head portion, the third shoulder portion being disposed at the second end of the third shaft portion, the third threaded portion extending from the second end of the third shaft portion; and

the third shoulder bolt being disposed such that the third head portion is disposed against the first end plate and the third shaft portion extends through the third aperture of the first end plate and the third aperture of the frame member, and the third shoulder portion is disposed against the second end plate and the third threaded portion extends through the third aperture of the second end plate and is threadably received in a third nut disposed against the second end plate.

4. The battery module of claim **3**, further comprising:

a fourth shoulder bolt having a fourth head portion, a fourth shaft portion, a fourth shoulder portion, and a fourth threaded portion; the fourth shaft portion having a first end and a second end, the first end of the fourth shaft portion extending from the fourth head portion, the fourth shoulder portion being disposed at the second end of the fourth shaft portion, the fourth threaded portion extending from the second end of the fourth shaft portion; and

the fourth shoulder bolt being disposed such that the fourth head portion is disposed against the first end plate and the fourth shaft portion extends through the fourth aperture of the first end plate and the fourth aperture of the frame member, and the fourth shoulder portion is disposed against the second end plate and the fourth threaded portion extends through the fourth aperture of the second end plate and is threadably received in a fourth nut disposed against the second end plate.

5. The battery module of claim **1**, wherein the first and second end plates are constructed of steel.

6. The battery module of claim **5**, wherein the frame member is constructed at least partially of plastic.

7. The battery module of claim **1**, wherein the first end plate has first, second, third, and fourth peripheral corner regions, the first, second, third, and fourth apertures of the first end plate extending through the first, second, third, and fourth peripheral corner regions, respectively, of the first end plate.

8. The battery module of claim **7**, wherein the frame member has first, second, third, and fourth peripheral corner regions, the first, second, third, and fourth apertures of the frame member extending through the first, second, third, and fourth peripheral corner regions, respectively, of the frame member.

9. The battery module of claim **7**, wherein a distance between the first and second end plates is equal to a longitudinal distance from the first head portion to the first shoulder portion.

10. A method of assembling a battery module, comprising:

providing a first end plate having first, second, third and fourth apertures extending therethrough;

providing a frame member having first, second, third, and fourth apertures extending therethrough;

providing first and second battery cells;

providing a second end plate having first, second, third and fourth apertures extending therethrough, the second end plate further having a first side and a second side disposed opposite to the first side;

providing a first shoulder bolt having a first head portion, a first shaft portion, a first shoulder portion, and a first threaded portion; the first shaft portion having a first end and a second end, the first end of the first shaft portion extending from the first head portion, the first shoulder portion being disposed at the second end of the first shaft portion, the first threaded portion extending from the second end of the first shaft portion;

disposing the first battery cell between the first end plate and the frame member;

disposing the second battery cell between the second end plate and the frame member; and

positioning the first shoulder bolt such that the first head portion is disposed against the first end plate and the first shaft portion extends through the first aperture of the first end plate and the first aperture of the frame member, and the first shoulder portion is disposed directly against and contacts the first side of the second end plate and the first threaded portion extends through the first aperture of the second end plate and is threadably received in a first nut, and the first nut is disposed directly against and contacts the second side of the second end plate.

11. The method of claim **10**, further comprising:

providing a second shoulder bolt having a second head portion, a second shaft portion, a second shoulder portion, and a second threaded portion; the second shaft portion having a first end and a second end, the first end of the second shaft portion extending from the second head portion, the second shoulder portion being disposed at the second end of the second shaft portion, the second threaded portion extending from the second end of the second shaft portion; and

positioning the second shoulder bolt such that the second head portion is disposed against the first end plate and the second shaft portion extends through the second aperture of the first end plate and the second aperture of the frame member, and the second shoulder portion is disposed against the second end plate and the second threaded portion extends through the second aperture of the second end plate and is threadably received in a second nut disposed against the second end plate.

12. The method of claim **11**, further comprising:

providing a third shoulder bolt having a third head portion, a third shaft portion, a third shoulder portion, and a third threaded portion; the third shaft portion having a first end and a second end, the first end of the third shaft portion extending from the third head portion, the third shoulder portion being disposed at the second end of the third shaft portion, the third threaded portion extending from the second end of the third shaft portion; and

positioning the third shoulder bolt such that the third head portion is disposed against the first end plate and the third shaft portion extends through the third aperture of the first end plate and the third aperture of the frame member, and the third shoulder portion is disposed against the second end plate and the third threaded portion extends through the third aperture of the second end plate and is threadably received in a third nut disposed against the second end plate.

13. The method of claim **12**, further comprising:

providing a fourth shoulder bolt having a fourth head portion, a fourth shaft portion, a fourth shoulder portion, and a fourth threaded portion; the fourth shaft portion having a first end and a second end, the first end of the fourth shaft portion extending from the fourth head portion, the fourth shoulder portion being disposed at the second end of the fourth shaft portion, the fourth threaded portion extending from the second end of the fourth shaft portion; and

positioning the fourth shoulder bolt such that the fourth head portion is disposed against the first end plate and the fourth shaft portion extends through the fourth aperture of the first end plate and the fourth aperture of the frame member, and the fourth shoulder portion is disposed against the second end plate and the fourth threaded portion extends through the fourth aperture of the second end plate and is threadably received in a fourth nut disposed against the second end plate.

14. A battery module, comprising:

a first metal end plate having first, second, third and fourth apertures extending therethrough;

a plastic frame member having first, second, third, and fourth apertures extending therethrough;

a first battery cell disposed between the first metal end plate and the plastic frame member;

a second metal end plate having first, second, third and fourth apertures extending therethrough, the second metal end plate further having a first side and a second side disposed opposite to the first side;

a second battery cell disposed between the second metal end plate and the plastic frame member;

a first shoulder bolt having a first head portion, a first shaft portion, a first shoulder portion, and a first threaded portion; the first shaft portion having a first end and a second end, the first end of the first shaft portion extending from the first head portion, the first shoulder portion being disposed at the second end of the first shaft portion, the first threaded portion extending from the second end of the first shaft portion; and

the first shoulder bolt being disposed such that the first head portion is disposed against the first metal end plate and the first shaft portion extends through the first aperture of the first metal end plate and the first aperture of the plastic frame member, and the first shoulder portion being disposed directly against and contacting the first side of the second metal end plate, and the first threaded portion extending through the first aperture of the second metal end plate and being threadably received in a first nut.

15. The battery module of claim **14**, wherein the first nut being disposed directly against and contacting the second side of the second metal end plate.

* * * * *